Tel. No.: VICtoria 6826
Any communication on the subject of this letter should be addressed to—
THE UNDER SECRETARY OF STATE,
HOME OFFICE (A.R.P. DEPT.),
HORSEFERRY HOUSE,
THORNEY STREET,
LONDON, S.W.1.
and the following number quoted:—
701,602/109

HOME OFFICE,
AIR RAID PRECAUTIONS DEPT.,
HORSEFERRY HOUSE,
THORNEY STREET,
LONDON, S.W.1.

31*st December*, 1937.

SIR,

Experiments in Anti-Gas Protection of Houses

I am directed by the Secretary of State to transmit, for the information of your Council, the annexed Report describing in detail the experiments to which reference was made by the Parliamentary Under Secretary of State in his speech on the second reading of the Air Raid Precautions Bill in the House of Commons on the 16th November.

The experiments were conducted by the Chemical Defence Research Department under the aegis of a special Sub-Committee of the Chemical Defence Committee. That Sub-Committee was composed of eminent experts not in Government employment, and included a number of distinguished University professors and scientists.

I am,
Sir,
Your obedient Servant,
R. R. SCOTT.

The Clerk of the County Council.
The Town Clerk.
The Clerk to the District Council.

Issued to all
County Councils
County Borough Councils (and the Corporation of the City of London)
Metropolitan Borough Councils
Municipal Borough Councils
Urban and Rural District Councils
in England and Wales
Copies sent for information to Chief Officers of Police in England and Wales.

PROTECTION AGAINST GAS

REPORT OF EXPERIMENTS CARRIED OUT BY THE CHEMICAL DEFENCE RESEARCH DEPARTMENT

Handbook No. 1 issued by the Air Raid Precautions Department of the Home Office describes the steps which the public are advised to take in order to protect themselves against the effects of any chemical warfare gases which might be employed by enemy aircraft in time of war.

The gist of these recommendations is:—

First, to go indoors.

Secondly, to arrange for the room into which you go to be made as gas-proof as possible.

Thirdly, to take with you the respirator which will have been issued to you.

Whilst it has never been claimed that any one of these steps by itself will make an individual completely safe, experiments and trials have shown that each of these measures is by itself of considerable value and that when all of them are adopted a very high degree of protection is obtained. An outline is given below of certain typical experiments which have been carried out.

These particular experiments were carried out with four different types of actual war gas. The first four experiments to be described will show the degree of protection that is obtained from each type of gas merely by going indoors and shutting the doors and windows.

As explained in Handbook No. 1*, a chemical warfare gas may be dropped from aircraft either as spray or in bombs. In the former case the liquid drops fall like rain, and it is obvious that by going indoors the public will avoid them. On the other hand, if gas bombs are dropped, people who have gone indoors will avoid being splashed by the chemical in the bomb, and even in an ordinary room they will receive some protection from the gas cloud. The amount of protection obtained in a house which has not been treated in any way can be gathered from the following experiments.

(a) *Protection obtained in a house which has not been treated in any way.*

The house employed was a gamekeeper's cottage with three rooms on the ground floor and three rooms upstairs. It had been unoccupied for about 15 years but was in a reasonable state of repair. It was to a large extent sheltered by belts of

* A.R.P. Handbook No. 1, "Personal Protection against Gas", price 6d. (8d. post free): published by H.M. Stationery Office (see back page).

trees which reduced the strength of the wind in the vicinity of the cottage to about one-eighth of that in the open. In this respect therefore the location of the cottage resembled a house in a town. In one experiment over a ton of actual chlorine gas was released 20 yards from the house so that the wind carried it straight on to the unprotected room. A very strong gas cloud was thus maintained outside the house for about 40 minutes, during which time the gas gradually penetrated to the inside. A fire was burning in the hearth the whole time, and the only measures taken to exclude the gas consisted of closing the doors and windows in the normal way.

Human beings who occupied this unprotected room found that gas penetrated slowly into the room, and after about seven minutes is became necessary for them to put on their respirators. Had these men been outside the house, they would have been compelled to put on their respirators immediately, since otherwise the very intense gas cloud would have caused instantaneous incapacitation and ultimate death.

If the gas, which with its containers weighed about 2½ tons, had been released more quickly, the strength of the gas cloud would have been greater but the time during which the house was enveloped by it would have been correspondingly shorter.

It is important to appreciate properly the severity of this trial. The quantity of gas concentrated on this house could under practical conditions only be obtained by several large bombs dropping very close to the building. The period of exposure to the maximum effects of the gas was also many times longer than would normally be experienced under most practical conditions, since the initial cloud from a gas bomb soon begins to be diluted and dispersed by the action of even quite moderate winds. It is clear that conditions similar to those of the experiment are extremely severe, and are such as would be likely to occur very rarely indeed and to a very small number of houses.

It should also be noted that the cottage used in this experiment had no carpets or other floor coverings. Most of the gas which leaked in came through the spaces between the floor boards, and it is therefore clear that much less would have got into an ordinary room in which there was a carpet, linoleum, or a solid floor.

In another experiment the house was surrounded at a distance of 20 yards by large shallow trays which were filled with mustard gas, the trays being spaced a few yards apart. By this means the vapour given off by the mustard gas was carried on to the house no matter how the direction of the wind varied. As the weather at the time was not very warm, the conditions of the experiment were made more severe by producing a fine spray of mustard gas at a point 10 yards to windward of

the house so that the house was enveloped in the resultant cloud of mustard gas for a period of an hour. The cloud produced in this way was about a hundred times as strong as that caused by the evaporation of the mustard gas from the trays. Animals were placed in an unprotected room in the house and remained there during the spraying period and for a further 20 hours while the house was subjected to the vapour of mustard gas given off from the trays. Observations made upon the animals during the three subsequent days and also post mortem examination showed that none of them was seriously harmed by the mustard gas.

The third type of gas used was tear gas. In this experiment the same cottage was enveloped for an hour in an intense atmosphere of tear gas produced by spraying the gas into the air at a point 10 yards upwind of the house. Men who were stationed 200 yards downwind from the house and in the track of the gas cloud were incapacitated in about a minute, and in some cases in 20 seconds. On the other hand, men who occupied rooms in the house which had received no treatment beyond the closing of the windows and doors found no need to put on their respirators for the first 13 minutes. The tear gas gradually penetrated into these unprotected rooms, although after three-quarters of an hour the strength of the gas inside the house was still very much less than that outside.

In the fourth experiment the cottage was enveloped for 20 minutes in a dense cloud of arsenical smoke. Men occupying an unprotected room of the house found that the arsenical smoke penetrated into the room, but the strength of the cloud inside was much less than that outside. When Civilian respirators were worn in this room, complete protection was obtained. Men who were stationed 200 yards downwind of the house and in the path of the gas cloud were rapidly affected, but when they wore Civilian respirators no effects were felt.

The above four examples clearly demonstrate that, apart from the protection which a house provides against falling airplane spray, some measure of protection is afforded even by an ordinary unprotected room against gas clouds such as are produced by bombs close to the building.

(b) *Protection afforded by a house treated in accordance with Air Raid Precautions Handbook No. 1.*

A brief account will now be given of four further experiments with the same four war gases in order to illustrate the added protection which can be obtained by treating a room in accordance with the instructions given in Air Raid Precautions Handbook No. 1. These experiments were also conducted with the cottage already mentioned. The room selected for treatment was situated on the ground floor on the windward side

of the house so that it was subjected to the full effect of the gas and the wind. It measured about 12 feet square. The Air Raid Precautions instructions for excluding gas were carried out by unskilled men, the official procedure being rigidly followed. As the house was not provided with carpets or other floor covering, it became necessary to seal up the joints between the boards over the whole of the floor of the selected room. This was done by pasting strips of paper along the joints between the floor boards. Some of these strips became displaced by the boots of the men who were inside the room, and an appreciable leakage of gas into the room undoubtedly occurred due to this cause. Two tons of chlorine were released 20 yards from the house, the time of emission being an hour. Animals were placed in the house, some in the " gas protected " room and others in rooms which had received no such treatment. The latter set of animals were killed by the gas which penetrated into the unprotected rooms under these very severe conditions. The animals in the " gas protected " room, however, were unaffected and remained normal, notwithstanding the severity of the trial.

An experiment with mustard gas, similar to that already described, was also carried out after the ground floor room on the windward side of the house had been treated in accordance with the Air Raid Precautions Department's procedure. Animals were placed in the room, which was then subjected to the same exposure of mustard gas spray and vapour as before. At the end of 20 hours the animals were removed and a most thorough examination of them showed no evidence of the effects of the gas at all. Animals placed outside the house during the first hour of the experiment were, of course, very seriously affected. The amount of mustard gas penetrating into the room was also measured by chemical methods and it was found that the amount of gas inside the room was so small that a man could have remained there for the whole 20 hours without its being necessary for him to wear a respirator and without any subsequent ill-effects.

The experiment with tear gas previously described was also performed against the " gas protected " room. A number of men occupied this room and found they were able to remain there without its being necessary for them to put on their respirators at any time during the hours that this very severe experiment lasted.

An experiment with arsenical smoke, similar to that already described, was also carried out against the " gas protected " room. The occupants found that the arsenical smoke penetrated the room to an extent which caused some irritation of the nose and throat and eventually rendered the wearing of respirators desirable to ensure comfort. After putting on the respirator, no

discomfort was felt throughout the remainder of the experiment. Men who left the " gas protected " room wearing their Civilian respirators were able to traverse the densest part of the cloud without discomfort. Under these severe conditions the presence of the arsenical smoke could be detected, but the effects were insignificant.

It is important to appreciate fully the severity of the conditions imposed in the two trials with arsenical smoke. A very high concentration of the irritant smoke was maintained around the house for 20 minutes. Under practical conditions such a high concentration could be produced only by a large and efficiently designed bomb falling close to the building, and then only for a short period. The conditions of the trials were therefore extremely severe and represent a situation which would only rarely be met, and in which only a small number of houses would be involved.

From this second series of experiments it will be seen that treating a room in accordance with the recommendations of the Air Raid Precautions Department does reduce very considerably the amount of gas penetrating into the room, and that a room so treated is correspondingly safer than a room which has received no such treatment.

Indeed, in the case of the experiments with mustard gas and tear gas, the amount of gas which was able to penetrate into the gas protected room was so small that no further measures of protection were necessary.

In the experiment with chlorine, although the amount of gas which entered the treated room was insufficient to injure the animals, human beings who occupied the room during this extremely severe test could smell the gas. They were provided with Civilian respirators, and they found that by putting these respirators on they were completely protected against every trace of gas. Some of these individuals then left the " gas protected " room, passed out of the house, and traversed the lethal cloud of gas which enveloped it. Although they deliberately stood in the densest part of the cloud for some minutes, no trace of the gas passed through their respirators.

Similarly the experiments with arsenical smoke show that although, under the most severe conditions, the cloud may penetrate into the " gas protected " room in sufficient quantity to be detected, or even to cause some irritation, the effects are materially reduced in a room so treated. It is also demonstrated that wearing a Civilian respirator affords complete protection against any smoke which may gain access to the room. The respirator also enabled individuals to pass through an extremely dense cloud of arsenical smoke in complete safety.

The experiments which have been outlined in this statement were purposely designed to represent the most severe conditions likely to be met. The results all combine to show that if the instructions given in Air Raid Precautions Handbook No. 1 are carried out a very high standard of protection is obtained. With regard to the first precaution it has been shown that going indoors and closing the doors and windows affords some measure of protection, even though the room occupied has not been specially prepared. In these circumstances there is ample time to put on the respirator at leisure if this should be necessary. If the second precaution of rendering the room as gas-proof as possible has been carried out, then the occupants will normally be able to remain in complete safety and comfort without further protection. Under the most severe conditions sufficient gas may penetrate such protected rooms to be recognized or even to cause slight irritation. When this occurs the respirator can be put on though in many cases this will be as a matter of convenience and extra precaution rather than real necessity. With regard to the Civilian respirator it has been shown that this will, in conjunction with the above precautions, provide complete safety for any period for which it is likely to be required. It has further been demonstrated that this respirator will enable the wearer to reach a place of safety even if he should for a time be exposed to the most dangerous situation—for example if he is caught out of doors in a gas cloud, or if his gas-protected room becomes damaged and he is compelled to seek shelter elsewhere.

(47178—34 Wt. 3276—235 20,000 12/37 P. St G. 373

LONDON
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120 George Street, Edinburgh 2;
26 York Street, Manchester 1; 1 St. Andrew's Crescent, Cardiff;
80 Chichester Street, Belfast;
or through any bookseller

1937
Price 2*d*. net

S.O. Code No. 34-9999

French family at Marbache, Meurthe et Moselle, France, September 1918. Gas masks were compulsory in the village, due to nearby gas attacks. Photo is the frontispiece of the October 1921 reprint of Will Irwin's book "The Next War" (Dutton, N.Y., 19th printing Oct 1921; first published April 1921.)

J. Davidson Pratt, "Gas Defence from the Point of View of the Chemist" (Royal Institute of Chemistry, London, 1937): "... during the Great War, French and Flemish ... living in the forward areas came unscathed through big gas attacks by going into their houses, closing the doors - the windows were always closed in any case - and remaining there..."

London 1941 baby gas mask drill

[*Notified in Army Orders for October*, 1935

26
Manuals
1441

DEFENCE AGAINST GAS

1935

By Command of the Army Council,

H. J. Creedy

THE WAR OFFICE,
31*st October*, 1935.

LONDON
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses:
Adastral House, Kingsway, London, W.C.2; 120 George Street, Edinburgh 2;
York Street, Manchester 1; 1 St. Andrew's Crescent, Cardiff;
80 Chichester Street, Belfast;
or through any Bookseller

1935

Price 1*s*. 0*d*. Net.

57–534

the use of shell or bombs containing non-persistent gas are unlikely to take place during the daytime, particularly in summer.

2. *The wind.*—

i. *Velocity.*—The higher the wind velocity, the greater the quantity of gas required. Consequently winds of low velocity (5 miles an hour) are favourable for the employment of gas, particularly cloud attacks, which then drift over an extended area to a considerable depth.

Winds of high velocity (greater than 12 miles an hour) rapidly disperse non-persistent gas. They decrease the efficiency of persistent gas by assisting evaporation.

Wind velocity is reduced by woods and hills.

ii. *Regularity.*—Irregular or squally winds tend to disperse gas and are unfavourable to its employment.

(Generally gas is dispersed fast)

i. Unsheltered ground, such as open slopes, exposes gas to the full effect of atmospheric conditions and thus tends to reduce its persistency.

ii. Sheltered areas, such as woods, enclosures and sunken roads, prolong the persistency of gas.

iii. During clear nights gas clouds tend to flow into gullies and valleys, leaving the tops of hills comparatively free; their effect is not appreciably reduced by passage over water.

iv. Thick woods in leaf will afford some measure of protection against gas sprayed from aircraft. There may be danger from vapour subsequently.

v. In towns and villages, blister gas will persist longer and non-persistent gas will disperse more slowly than in open country, owing to the screening effect of houses. Aircraft spray will be less effective against personnel owing to the cover available.

vi. For protection from both H.E. and gas a basement or cellar suitably gas-proofed is best; if neither of these is available, the first floor should be selected.

12. Gas-proof shelters and rooms

1. *Gas-proof shelters.*—The provision of gas-proof shelters in which troops may feed or rest will seldom be possible or even necessary in mobile warfare. It may sometimes be desirable, however, to provide gas-proof shelters for head-quarters, signal centres and aid posts ; such shelters should have gas-tight doors or curtains as described in the Manual of Field Engineering, Vol. I (All Arms). If two curtains are used, complete protection is obtained, as it is possible to enter or leave the shelter without introducing appreciable quantities of gas. A box or heap of bleaching powder should be placed at the entrance of the shelter for men to stand in before entering.

2. *Gas-proof rooms.*—Since any part of the theatre of war within radius of hostile aircraft may be attacked, rooms, whether in billets or barracks, in which troops are quartered should be rendered reasonably gas-proof by the following measures :—

i. Where the room is likely to be occupied for a long period—nail *cloth, union anti-gas,* which has been treated with heavy oil, above the windows and doors, after which it should be rolled up ready to let down. A supply of tin tacks should be kept in each room for nailing the sides of the cloth to the wall when it is let down. If *cloth, union anti-gas,* is not available, ordinary blankets may be used. They should be kept damp with water, or preferably with heavy oil if available, as they are then more effective. In addition, a supply of rags or paper should be

(Plastic sheets and duct tape for broken windows)

kept in each room for stopping up the chimney and for stuffing into cracks, round windows and under doors.

ii. When the room is to be occupied for one night only or where no blankets are available—a supply of rags or paper should be kept in each room for stopping up the chimney, and for stuffing into cracks, round windows and under doors.

Breathe Freely !

THE TRUTH ABOUT POISON GAS

by

JAMES KENDALL

M.A., D.Sc., F.R.S.

Professor of Chemistry in the University of Edinburgh ;
formerly Lieutenant-Commander in the United
States Naval Reserve, acting as Liaison Officer
with Allied Services on Chemical Warfare

LONDON

G. BELL & SONS LTD

1938

CASUALTIES IN INITIAL GAS ATTACKS

Gas	*Date*	*Amount Used In Tons*	*Lethal Concentration* *	*Non-fatal injuries*	*Deaths*
Chlorine	Apr. 22, 1915	168	5·6	15,000	5,000
Phosgene	Dec. 19, 1915	88	0·5	1,069	120
Mustard	July 12, 1917	125	0·15	2,490	87

(* mg/litre for 10 minutes exposure unprotected)

between September 15 and November 11, 1918, 2,000,000 rounds of gas shell, containing 4,000 tons of mustard gas, were fired against the advancing British troops; our losses therefrom were 540 killed and 24,363 injured. Gas defence had progressed to the point where it took nearly 8 tons of mustard gas to kill a single man !

The first salvo of gas shells often reaches the trenches before the occupants don their masks, whereas the Londoner will receive ample warning of the approaching danger.

The alarmist and the ultra-pacifist love to quote the fact that one ton of mustard gas is sufficient to kill 45,000,000 people. This would indeed be true if the 45,000,000 people all stood in a line with their tongues out waiting for the drops to be dabbed on, but they are hardly likely to be so obliging. One steam-roller would suffice to flatten out all the inhabitants of London if they lay down in rows in front of it, but nobody panics at the sight of a steam-roller.

Chemicals in War, by Colonel Prentiss:

'Public psychology is an increasingly determining factor in modern warfare. The threat of air attacks, accompanied by the use of war gases against civil population, constitutes an important psychological weapon which an unscrupulous enemy may employ. All military experience with chemical warfare, however, shows that gas may be effectively countered by organized protection.

excellent pamphlet was issued in 1934; it was called *Don't be Afraid of Poison Gas* and consisted of hints for civilians in the event of a poison-gas attack. Its author, Mr. F. N. Pickett, was charged after the war with the task of destroying the greatest accumulation of poison gases the world has ever seen – that contained in the ammunition dumps in France

A few short extracts from this pamphlet, compressed into one quotation, will illustrate its main line of argument:

'The object of an enemy gas attack on a city would be to obtain the maximum psychological effect. That is to say an enemy is not so much interested in killing civilians as in driving them into hysteria and panic, so that they will clamour for peace at any price.'

Chemicals in War, by Lieutenant-Colonel A. M. Prentiss, Ph.D., of the United States Chemical Warfare Service:

'Such propaganda, capitalizing general ignorance of chemical-warfare agents, is seized upon and amplified by sensational *revelations* appearing in popular but unscientific discussions of the subject.'

It is the fright and hatred of ignorance.

the only method which Bertrand Russell can recommend to enable us to escape Bedlam is as follows:

'There is in France a powerful movement in favour of complete pacifism, which lately secured a majority at a congress of school-teachers [!] . . . Suppose England and France were both to disarm. If the Nazis endeavoured to continue their military parades and their glorification of war they would cease to look heroic and would become ridiculous . . .'

(B. Russell, Which Way to Peace?, 1936 gas book)

Imagine the joy with which Hitler and Mussolini would seize such a heaven-sent opportunity to extend their domination over self-confessed decadent and inferior races !

EVER since the Armistice, three classes of writers have been deluging the long-suffering British public with lurid descriptions of their approaching extermination

These three classes are pure sensationalists, ultra-pacifists and military experts.

perpetrators of such articles may not recognize themselves that what they are writing is almost entirely imaginary, but they do want to get their manuscript accepted for the feature page of the *Daily Drivel* or the *Weekly Wail*. In order to do that, they must pile on the horrors thick, and they certainly do their best

The amount of damage done by such alarmists cannot be calculated, but it is undoubtedly very great.

poison gas has a much greater news value. It is still a new and mysterious form of warfare, it is something which people do not understand, and what they do not understand they can readily be made to fear.

The recent film *Things to Come*, in particular, has provided a picture of chemical warfare of the future which shows how simply and rapidly whole populations will be wiped out. Millions of people, perhaps, have been impressed by the authority and reputation of Mr. H. G. Wells into believing that this picture represents the plain truth.

EXHIBIT 'B' is the work of the ultra-pacifist. He abominates war and everything connected with war to such an extent that he paints a highly coloured picture of its horrors, in the most extreme Surrealistic style, with the object of frightening the public to the point where they will relinquish, in the hope of escaping war, even the right of self-defence. His motives may be praiseworthy, but his methods are to be deplored.

HOME OFFICE

THE PROTECTION OF YOUR HOME AGAINST AIR RAIDS

READ THIS BOOK THROUGH
THEN
KEEP IT CAREFULLY

Why this book has been sent to you

If this country were ever at war the target of the enemy's bombers would be the staunchness of the people at home. We all hope and work to prevent war but, while there is risk of it, we cannot afford to neglect the duty of preparing ourselves and the country for such an emergency. This book is being sent out to help each householder to realise what he can do, if the need arises, to make his home and his household more safe against air attack.

The Home Office is working with the local authorities in preparing schemes for the protection of the civil population during an attack. But it is impossible to devise a scheme that will cover everybody unless each home and family play their part in doing what they can for themselves. In this duty to themselves they must count upon the help and advice of those who have undertaken the duty of advice and instruction.

If the emergency comes the country will look for her safety not only to her sailors and soldiers and airmen, but also to the organised courage and foresight of every household. It is for the volunteers in the air raid precautions services to help every household for this purpose, and in sending out this book I ask for their help.

Samuel Hoare

1938

HOW TO CHOOSE A REFUGE-ROOM

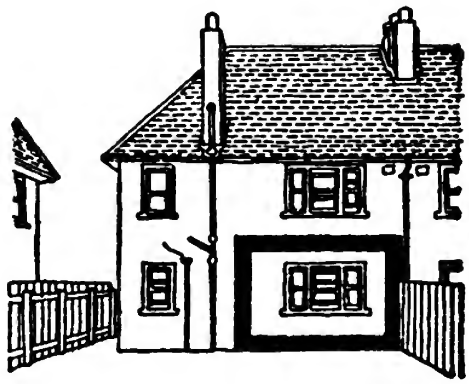
Almost any room will serve as a refuge-room if it is soundly constructed, and if it is easy to reach and to get out of. Its windows should be as few and small as possible, preferably facing a building or blank wall, or a narrow street. If a ground floor room facing a wide street or a stretch of level open ground is chosen, the windows should if possible be specially protected (see pages 30 and 31). The stronger the walls, floor, and ceiling are, the better. Brick partition walls are better than lath and plaster, a concrete ceiling is better than a wooden one. An internal passage will form a very good refuge-room if it can be closed at both ends.

A cellar or basement is the best position for a refuge-room if it can be made reasonably gas-proof

The best floor for a refuge-room

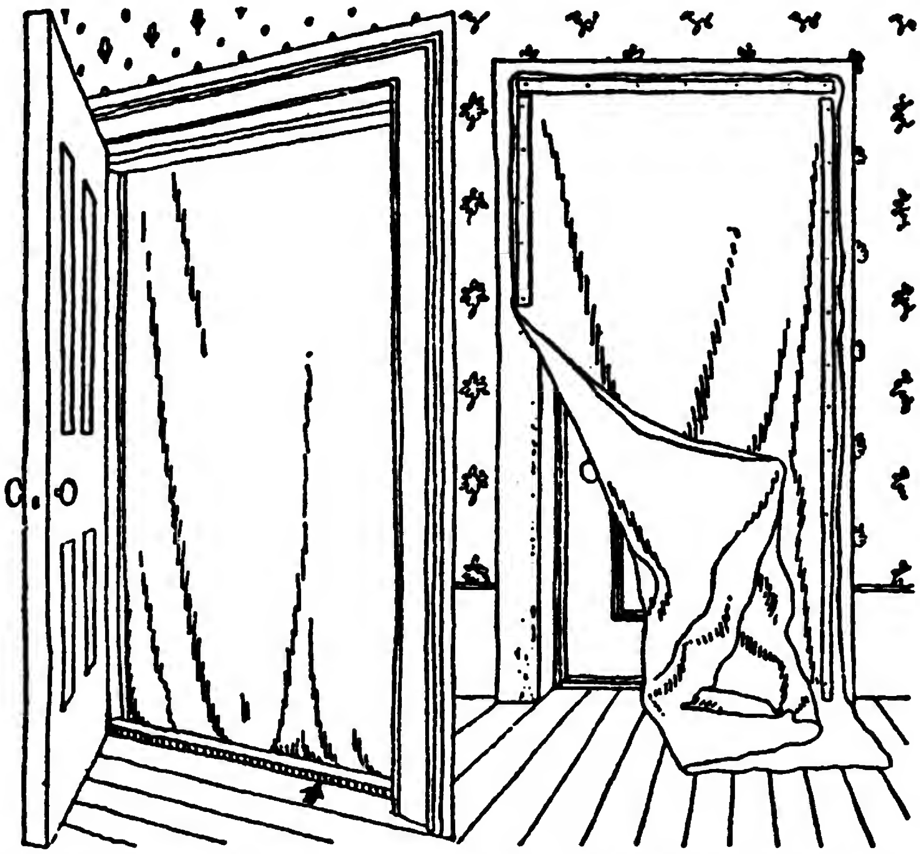
A cellar or basement is the best place for a refuge-room if it can be made reasonably gas-proof and if there is no likelihood of its becoming flooded by a neighbouring river that may burst its banks, or by a burst water-main. If you have any doubt about the risk of flooding ask for advice from your local Council Offices.

Alternatively, any room on any floor below the top floor may be used. Top floors and attics should be avoided as they usually do not give sufficient protection overhead from small incendiary bombs. These small bombs would probably penetrate the roof but be stopped by the top floor, though they might burn through to the floor below if not quickly dealt with.



In a house with only two floors and without a cellar, choose a room on the ground floor so that you have protection overhead

How to seal up the door



(Plastic sheets and duct tape for broken windows)

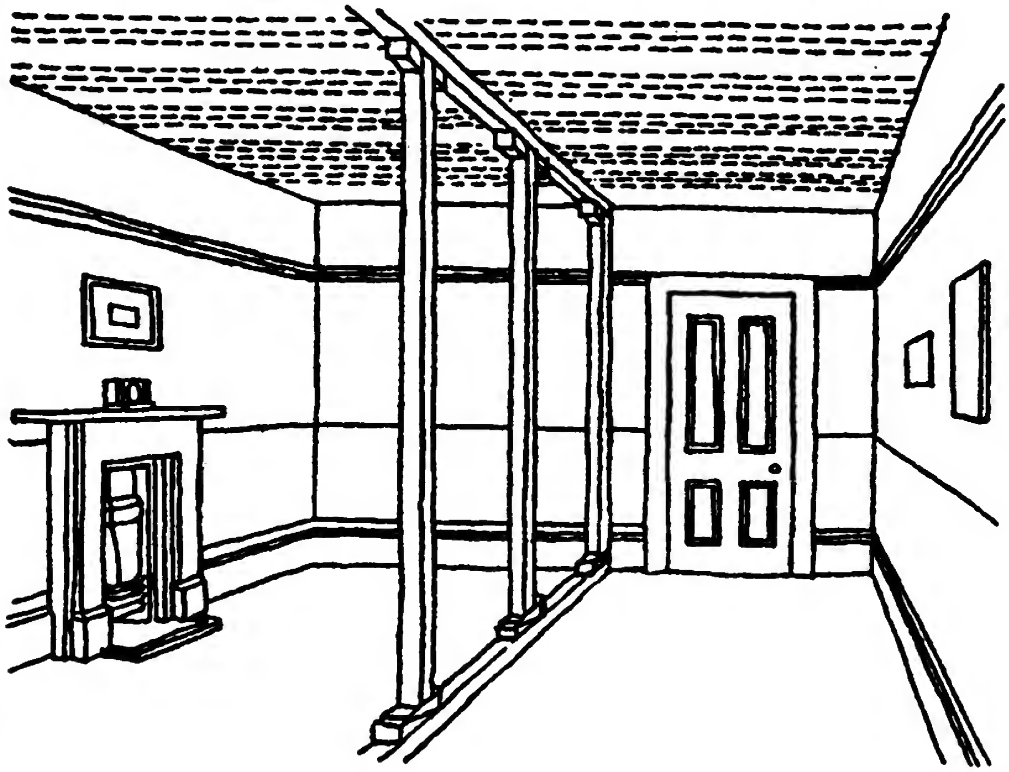
Doors which have to be opened and closed should be sealed against gas. This is how to do it.

Nail a piece of wood, padded with felt, to the floor so that the door, when closed, presses tightly against it. Take care not to nail this piece of wood on the wrong side of the door so that it cannot be opened. Strips of felt may also be nailed round the inside of the door to exclude draughts. Fix a blanket outside the door if the door opens inwards, or inside the door if the door opens outwards, with strips of wood. The top of the blanket should be fixed to the top of the door frame. One side of the blanket should be fastened down the whole length of the door frame, on the side where the hinges are, by means of a strip of wood nailed to the frame. The other side of the blanket should be secured not more than two feet down, so that a flap is left free for going in and out. Arrange the blanket so that at least 12 inches trails on the floor to stop air from blowing underneath it. See illustration above. If the blanket is kept damp during an air raid, it will give better protection.

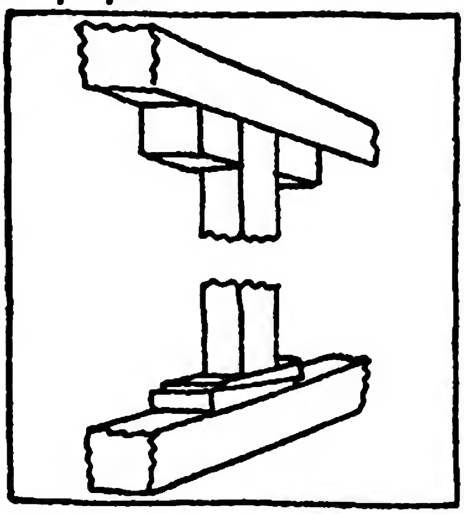
Strengthening the room

If your refuge-room is on the ground floor or in the basement, you can support the ceiling with wooden props as an additional protection. The illustration shows a way of doing this, but it would be best to take a builder's advice before setting to work. Stout posts or scaffold poles are placed upright, resting on a thick plank on the floor and supporting a stout piece of timber against the ceiling, at right angles to the ceiling joists, i.e. in the same direction as the floor boards above.

How to support a ceiling



The illustration below shows the detail of how to fix the props



The smaller illustration shows how the posts are held in position at the top by two blocks of wood on the ceiling beam. The posts are forced tight by two wedges at the foot, driven in opposite ways. Do not drive these wedges too violently, otherwise you may lift the ceiling and damage it. If the floor of your refuge-room is solid, such as you might find in a basement, you will not need a plank across the whole floor, but only a piece of wood a foot or so long under each prop.

How to deal with an incendiary bomb

You can tackle a small incendiary bomb yourself (better if you have someone to help you) if you will follow these directions. You will also be able to get proper instruction about it.

The bomb will burn fiercely for a minute or so, throwing out burning sparks, and afterwards less fiercely. It will set fire to anything inflammable within reach. You should try to deal with it before it has caused a big fire.

Before you can get close enough to do anything, you will probably have to cool down the room with water, preferably with a line of hose. (See page 20 for a simple hand pump.)

There are two ways of dealing with the bomb itself.

1. It can be controlled by means of the Stirrup Hand Pump (see page 20), with a *spray* of water which, although it does not extinguish the bomb, makes it burn out quickly and helps to prevent the fire spreading. Water must *not* be used on a bomb in any other way.

2. If it has fallen where you can get at it, it can be smothered with dry sand or earth. A bucket full of sand or earth is enough to cover and control a small bomb. The best method of applying it is by the Redhill sand container and scoop (see page 19); but a bucket will do if you have a long-handled shovel to use with it.

   Immediately the bomb is smothered, shovel or scoop it into the sand container or bucket and take it out of doors. If a bucket is used, 2 or 3 inches of sand or earth must be kept in the bottom to prevent the bomb burning through.

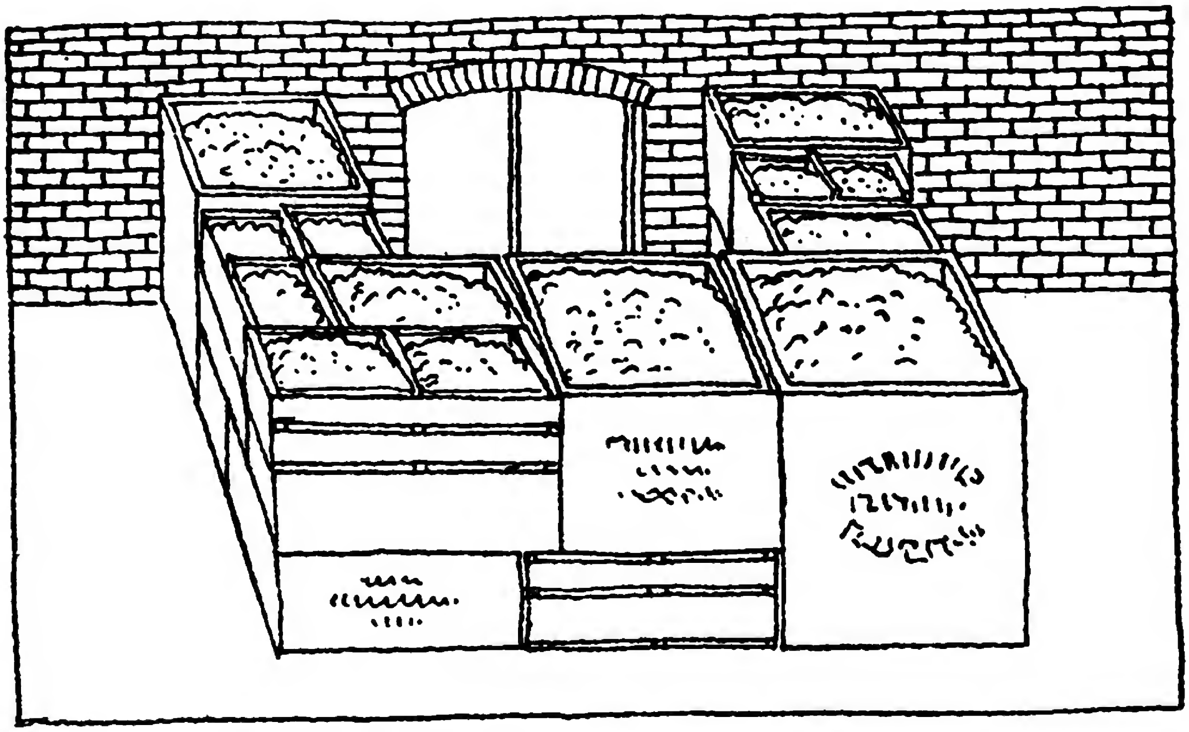
Remember that the bomb might burn through the floor before you have had time to remove it, and you might have to continue to deal with it on the floor below.

ACT PROMPTLY. PROMPT ACTION MAY BE THE MEANS OF SAVING LIVES. PROMPT ACTION WILL SAVE PROPERTY. PROMPT ACTION WILL PREVENT SERIOUS DAMAGE. PROMPT ACTION WILL DEFEAT THE OBJECT OF THE RAID.

EXTRA PRECAUTIONS AGAINST EXPLOSIVE BOMBS

TRENCHES. Instead of having a refuge-room in your house, you can, if you have a garden, build a dug-out or a trench. A trench provides excellent protection against the effects of a bursting bomb, and is simple to construct. Full instructions will be given in another book which you will be able to buy. Your air raid wardens will also be able to advise.

SANDBAGS. Sandbags outside are the best protection if your walls are not thick enough to resist splinters. Do not rely on a wall keeping out splinters unless it is more than a foot thick. Sandbags are also the best protection for window openings. If you can completely close the window opening with a wall of sandbags you will prevent the glass being broken by the blast of an explosion, as well as keeping out splinters. But the window must still be sealed inside against gas.



A basement window protected by boxes of earth

Any bags or sacks, including paper sacks such as are used for cement, will do for sandbags.

ALL persons involved in accidents suffer from shock, whether or not they suffer physical injury. Shock is a disturbance of the nervous system. It varies in its severity. The signs of shock are faintness, paleness, weak pulse, and weak breathing.

TREATMENT OF SHOCK

1 Place the patient flat on his back on a bed or a rug or on cushions. If you think a bone may be broken do not move the patient more than can be helped.

2 Loosen the clothing at the neck, chest and waist to make the breathing freer.

3 Cover the patient warmly with rugs and blankets. In cases of shock the body loses heat. A hot-water bottle is helpful, but take care that it does not lie in contact with the skin.

4 Give hot drinks. If you cannot make hot drinks, give cold water *in sips*. But only if the patient is conscious and able to swallow.

5 Soothe the patient by speaking reassuring words in a calm voice and in a confident way.

TREATMENT OF WOUNDS

The first thing to do is to stop the bleeding and to keep the wound clean. This can be done by covering it with a clean dressing bound on tightly. Do not touch a wound with your fingers because of the risk of poisoning from dirt. Treat the patient for shock in addition to attending to the wound, because the loss of blood, if the wound is serious, and the pain do in themselves cause shock.

WOUNDS IN THE HEAD AND BODY

1 Cover the wound with a clean folded handkerchief or a double layer of dry lint.

2 Apply another handkerchief or a layer of cotton wool as a pad to distribute the pressure over the wound.

3 Tie the dressing in position with a bandage, a strip of linen, or a necktie. This can be done quite firmly, unless there is any foreign body, especially glass, in the wound, or unless the bone is broken. In this case the dressing should be tied on lightly.

4 Treat the patient for shock.

ILLUSTRATION NO. 8.

The house in the upper photograph had a Government steel table shelter in a downstairs room and was blown up to reproduce the effect of a heavy bomb falling near. The whole house collapsed, burying the shelter under débris. In the lower photo the shelter can be seen still intact. It would have been possible for anyone in the shelter to get out unaided.

(Page 11 from the 1941 UK Ministry of Home Security "Shelter at Home" handbook.)

Morrison Shelters in Recent Air Raids.

A report of Ministry of Home Security experts on 39 cases of bombing incidents in different parts of Britain covering all those for which full particulars are available in which Morrison shelters were involved shows how well they have stood up to severe tests of heavy bombing.

All the incidents were serious. Many of the incidents involved direct hits on the houses concerned a risk against which it was never claimed these shelters would afford protection. In all of them the houses in which shelters were placed were within the radius of damage by bombs; in 24 there was complete demolition of the house on the shelter.

A hundred and nineteen people were sheltering in these "Morrisons" and only four were killed. So that 115 out of 119 people were saved. Of these only 7 were seriously injured and 14 slightly injured while 94 escaped uninjured. The majority were able to leave their shelters unaided.

CD 2333

[redacted]

HOME OFFICE

CD/SA 12
Copy. No 5.

OFFICE OF THE CHIEF SCIENTIFIC ADVISER

A COMPARISON BETWEEN THE NUMBER OF PEOPLE KILLED PER TONNE OF BOMBS DURING WORLD WAR I AND WORLD WAR II

BOMB SIZES

=> ≈ 175 kg

For World War II the average bomb weight was between 150 - 200 kg. (R.C. 268, Table 6), whereas for World War I the majority of bombs were 12 or 50 kg.

TABLE 5

Relative safeties in World War II deduced from population and casualty distribution

	In the open	Under cover	In shelter
Population exposure	5%	60%	35%
Location people killed	19%	62%	19%
Relative safety RELATIVE DANGER!	72%	20%	10%

(1) A house about $3\frac{1}{2}$ times as safe as in the open.
(2) A shelter about twice as safe as a house.

Table 6 also shows the location of killed which is implied by each of the possible population exposures. The only evidence available on this point is that, for the day raid on June 13th, 1916, in which the total number killed was 59, 69.5% of the people killed in the City were in the open.

SECRET.

W.P.(G)(41)7. COPY NO. 62

January 15th, 1941.

W A R C A B I N E T.

AIR RAID SHELTER POLICY.

Memorandum by the Minister of Home Security.

---

6. Shelter in the home: The Anderson shelter was originally intended for indoor use but for a number of reasons including the danger of fire an outdoor variant was adopted. Experience has shown that the objections to the indoor use of the Anderson or somewhat similar shelter are not so serious as was thought and two designs have been produced which can be erected indoors without support. These new types, although they may give slightly less protection than a well covered Anderson shelter out of doors, would fill the needs of a large section of the public, especially the middle class. One design allows the use of the shelter as part of the furniture of the room.

7. I regard shelters of this type as of the first importance and wish to provide them on a big scale. Each shelter will use over 3 cwt. of steel and will allow at a pinch two adults and one to two children to sleep inside. For an outlay of about 65,000 tons of steel, as a first instalment, I could therefore produce 400,000 shelters with accommodation for at least 1,000,000 persons. I should wish to complete such a programme within the first three months of production and thereafter at a similar or increasing rate. From enquiries I believe that manufacture can be arranged provided steel is supplied and if the Cabinet approves my policy I shall require their direction that the steel be made available.

10. Conclusions.

I ask for a general endorsement of the policy I have outlined in this paper and in particular for the agreement of my colleagues:

(i) that proposals for building shelters of massive construction should be rejected;

(ii) that steel should be made available to carry out the programme outlined in paragraph 7 for the provision of steel shelters indoors;

(iii) that the limit of income for the provision of free shelter for insured persons should be raised from £250 to £350 per annum.

H.M.

MINISTRY OF HOME SECURITY.
January 15th, 1941.

Printed for the War Cabinet. May 1941.

MOST SECRET. Copy No. 58

W.P. (G) (41) 44.
May 5, 1941.

TO BE KEPT UNDER LOCK AND KEY.

It is requested that special care may be taken to ensure the secrecy of this document.

WAR CABINET.

AIR RAIDS ON LONDON, SEPTEMBER–NOVEMBER 1940.

Memorandum by the Home Secretary and Minister of Home Security.

Framed buildings.

Most valuable information has been gained on the effects of bombs on framed buildings. Such buildings are practically immune to anything but a direct hit. Blast damage from bombs outside is usually confined to windows and internal partitions. Even parachute mines falling immediately outside the building or exploding on the roof produce negligible damage to structure or floors.

Relation of Casualties to Bombs Dropped.

From a knowledge of the number of bombs dropped and the casualties occurring in different boroughs, some idea can be gained of the effectiveness of bombs in producing casualties. The number of casualties per bomb varies widely from 1·59 in the least to 6·94 in the most populated boroughs, but it follows closely the apparent densities of population as shown in figure 1. The number of casualties per bomb is roughly a twelfth of the number of persons per acre, and the number of deaths per bomb about 1/60th of the number of persons per acre. From this it can be deduced that the mean distance at which injury from a bomb is likely to occur is 35 ft., and that at which the bomb is lethal is 15 ft.

The casualties per bomb in Central London fell steadily from an average of 3·7 in September to 2·7 in October and 1·7 in November. This corresponds to the considerable fall in population in most of the boroughs concerned.

Conclusion.

We may now say that we have a good general understanding, both qualitative and quantitative, of the effects of bombs on buildings and on cities. New types of bombs, particularly heavier bombs, may be used, but we can anticipate no startling change in the effects apart from increase in minor damage. With bombing of the present type the results of our work are to show that in urban areas, such as that of the County of London, *for one ton of bombs approximately* 10 *houses will be destroyed or will need pulling down.* 25 *more will be temporarily uninhabitable, and another* 80 *will be slightly damaged.* 80 *people will be made temporarily homeless and* 35 *will lose their homes permanently.* 25 *people, mostly among the latter category, will be wounded, the greater part of them slightly, and* 6 *will be killed or die from wounds.*

~~CONFIDENTIAL~~

DEPARTMENT OF THE ARMY TECHNICAL MANUAL
DEPARTMENT OF THE NAVY
DEPARTMENT OF THE AIR FORCE
MARINE CORPS PUBLICATIONS

TM 23-200
OPNAV INSTRUCTION 03400.1B
AFL 136-1
NAVMC 1104 REV

CAPABILITIES OF ATOMIC WEAPONS (U)

Prepared by
Armed Forces Special Weapons Project

DEPARTMENTS OF THE ARMY, THE NAVY AND THE AIR FORCE

REVISED EDITION NOVEMBER 1957

~~CONFIDENTIAL~~

c. Indirect Blast Injury.

(1) *General.* Indirect blast casualties result from burial by debris from collapsed structures with attendant production of fractures and crushing injuries, from missiles placed in motion by the blast wave, or from fire or asphyxiation where individuals are prevented from escaping the wreckage.

(2) *Personnel in structures.* A major cause of personnel casualties in cities is structural collapse and damage. The number of casualties in a given situation may be reasonably estimated if the structural damage is known. Table 6–1 shows estimates of casualty production in two types of buildings for several damage levels. Data from Section VII may be used to predict the ranges at which specified structural damage occurs. Demolition of a brick house is expected to result in approximately 25 percent mortality, with 20 percent serious injury and 10 percent light injury. On the order of 60 percent of the survivors must be extricated by rescue squads. Without rescue they may become fire or asphyxiation casualties, or in some cases be subjected to lethal doses of residual radiation. Reinforced concrete structures, though much more resistant to blast forces, produce almost 100 percent mortality on collapse. The figures of table 6–1 for brick homes are based on data from British World War II experience. It may be assumed that these predictions are reasonably reliable for those cases where the population is in a general state of expectancy of being subjected to bombing and that most personnel have selected the safest places in the buildings as a result of specific air raid warnings. For cases of no prewarning or preparation, the number of casualties is expected to be considerably higher. To make a good estimate of casualty production in structures other than those listed in table 6–1, it is necessary to consider the type of structural damage that occurs and the characteristics of the resultant missiles. Glass breakage extends to considerably greater ranges than almost any other structural damage, and may be expected to produce large numbers of casualties at ranges where personnel are relatively safe from other effects, particularly for an unwarned population.

Table 6–1. Estimated Casualty Production in Structures for Various Degrees of Structural Damage

	Killed outright	Serious injury (hospitalization)	Light injury (No hospitalization)
1–2 story brick homes (high explosive data):	*Percent*	*Percent*	*Percent*
Severe damage	25	20	10
Moderate damage	<5	10	5
Light damage	------	<5	<5
Reinforced-concrete buildings (Japanese data, nuclear):			
Severe damage	100	------	------
Moderate damage	10	15	20
Light damage	<5	<5	15

Note. These percentages do not include the casualties which may result from fires, asphyxiation, and other causes from failure to extricate trapped personnel. The numbers represent the estimated percentage of casualties expected at the maximum range where the specified structural damage occurs.

Personnel in a prone position are less likely to be struck by flying missiles than those who remain standing. 6–3

Table 6–2. Critical Radiant Exposures for Burns Under Clothing

(Expressed in cal/cm² incident on outer surface of cloth)

Clothing	Burn	1 KT	100 KT	10 MT
Summer Uniform	1°	8	11	14
(2 layers)	2°	20	25	35
Winter Uniform	1°	60	80	100
(4 layers)	2°	70	90	120

6–4

CUE

FOR SURVIVAL

OPERATION CUE

A. E. C. NEVADA TEST SITE

MAY 3, 1955

A REPORT BY THE

FEDERAL CIVIL DEFENSE

ADMINISTRATION

EFFECTS OF NUCLEAR WEAPONS

BY HAROLD L. GOODWIN,
Director, Atomic Test Operations, FCDA

A great deal of information has been released over the past several years on the effects of atomic explosions, yet many of these effects are still poorly understood by the general public. For that reason, the principal effects of a nuclear explosion are reviewed, with a brief discussion of factors of particular importance to civil defense.

This entire section is based on informaton available in published sources. There is a widespread but erroneous view that most information on the effects of nuclear explosions is classified, and hence is not available to the general public. Information that exists only in classified form generally is information which deals with refinements of weapons effects. A considerable amount of gross information on any major effect is available in a number of publications.

The best reference in this field is still the basic handbook, *The Effects of Atomic Weapons.* Despite the fact that this useful work was first published in 1950, queries daily to the Federal Civil Defense Administration indicate that it has not been widely studied or understood. A thoughtful reading will be of value to any person with civil defense responsibility. A revision, now in process, may be issued in the next few months.

The time of travel of the shock wave is not generally understood by many persons. The concept of "duck and cover," which would still be of great value in case of attack without warning, is based on the comparatively large time interval between the burst and arrival of the shock wave at a given point.

It takes several seconds for the shock wave of a nominal bomb to reach a point 2 miles from the burst. A person who moved promptly at the first light of the detonation would have time to get under or behind a convenient piece of furniture, or other protection. At greater distances there would be even more time.

This time lapse between the detonation and arrival of the shock wave was graphically demonstrated to persons watching from the observer areas in the Test Site. The detonation takes place, a phenomenon without sound from the viewpoint of the observer. So much time elapses between the detonation and arrival of the shock wave that observers sometimes forget that the shock wave is on its way and the loud bang of its arrival finds them unprepared. Persons are frequently startled and have even been pushed off balance by the shock wave. The pause between a lightning flash and the thunder is comparable.

The question may be asked, how will one know when a burst has gone off if the sound does not arrive for some time? The answer is that the light from the explosion is its own warning.

BIOMEDICAL EFFECTS OF THERMAL RADIATION

BY DR. HERMAN ELWYN PEARSE, *Professor of Surgery at the University of Rochester. Consultant to several Government departments, notably the Atomic Energy Commission's Division of Biology and Medicine. Consultant to the Armed Forces Special Weapons Project*

After the Bikini test, I was asked to go to Japan as a consultant for the National Research Council to survey the casualties in Nagasaki and Hiroshima. Being a surgeon, I was greatly impressed with the magnitude of the medical problem from burns and wounds very largely caused by flying missiles. They constituted roughly 85 percent of the casualties in Japan.
140

In Japan it was an August day, the people were lightly clothed, and they were out in the open.
141

Then we observed the healing of the wounds, and we found again that the wounds healed in the same manner as those that we had produced in the laboratory. There was some difference in these lesions from the ordinary burns of civil life, but I would predict, from what I learned from experiments, that the difference is on the good side. The burns look worse; they are often charred, but they may not penetrate as deeply, and the char acts as a dressing, nature's own dressing. The scab solidifies, and the healing process goes on under that scab, after which the scab is sequestrated, and the healed surface is revealed beneath.
142

I didn't care what happened to the fabrics; I wanted to know what happened to the man under the fabric. So we conceived this idea, that the important factor in studying clothing was what happened under the clothing; how it shielded the animal with cloth of different composition, weight, texture, weave, and color. We have made a great many studies both in the laboratory and in the field on this problem of the protective effect of clothing....

For example, if you have 2 layers, an undershirt and a shirt, you will get much less protection than if you have 4 layers; and if you get up to 6 layers, you have such great protection from thermal effects that you will be killed by some other thing. Under 6 layers we only got about 50 percent first degree burns at 107 calories.
143

If we can just increase the protection a little bit, we may prevent thousands and thousands of burns.

... For example, to produce a 50-percent level of second-degree burns on bare skin required 4 calories. When we put 2 layers of cloth in contact, it only took 6 calories. But separate that cloth by 5 millimeters, about a fifth of an inch, and it increases the protective effect 5 times. The energy required to produce the same 50-percent probability of a second-degree burn is raised up to 30 calories. So if you wear loose clothing, you are better off than if your wear tight clothing.
144

UR-261

Health and Biology

THE UNIVERSITY OF ROCHESTER
Atomic Energy Project
P. O. Box 287, Station 3
Rochester 20, New York

Contract W-7401-eng-49

* * *

STUDIES ON FLASH BURNS: THE PROTECTION AFFORDED BY 2, 4 AND 6 LAYER FABRIC COMBINATIONS

by:

George Mixter and Herman E. Pearse

Division: Special Programs

Division Head: H. A. Blair

Section: Flash Burn

Section Head: H. D. Kingsley

Submitted by: Henry A. Blair, Director

Date of Report: 6/4/53

STUDIES ON FLASH BURNS:

THE PROTECTION AFFORDED BY 2, 4 AND 6 LAYER FABRIC COMBINATIONS

by

George Mixter, Jr., M. D. and Herman E. Pearse, M. D.

ABSTRACT

Fabric interposed between a carbon arc source and the skin of Chester White pigs increased the amount of thermal energy required to cause 2+ burns. For the 2, 4 and 6 layers of fabric studied this increase was 3.6, 38 and over 104 cal/cm^2 respectively when the inner layer of fabric was in contact with the skin. Separation of the inner layer from the skin by 5 mm increased the protective effect of the 2 layer combination from 7.4 to 29 cal/cm^2, provided the outer layer was treated for fire retardation. If the outer layer was not so treated, sustained flaming occurred which in itself added to the thermal burn.

INTRODUCTION

In the past, work in this laboratory has been directed toward a study of flash burns in unshielded skin. It is well known from the atomic bombing in Japan that this type of burn was modified by clothing. A laboratory analysis of the protective effect of fabrics against flash burns was begun (5) by shielding the skin with a few representative fabrics and their combinations.

1. 2 Layers
   a. light green oxford
      knitted cotton underwear
   b. light green oxford (HPM)
      knitted cotton underwear
2. 4 Layers
   olive green sateen
   thin cotton oxford
   wool-nylon shirting
   knitted cotton underwear
3. 6 Layers
   olive green sateen
   thin cotton oxford
   mohair frieze
   rayon lining
   wool-nylon shirting
   knitted wool underwear

5. Morton, J. H., Kingsley, H. D., and Pearse, H. E., "Studies on Flash Burns: The Protective Effects of Certain Fabrics", Surgery, Gynecology and Obstetrics, 94, 497-501 (April 1952).

THE EFFECTS OF THE ATOMIC BOMBS AT HIROSHIMA AND NAGASAKI

REPORT OF THE BRITISH MISSION TO JAPAN

PUBLISHED
FOR THE HOME OFFICE AND THE AIR MINISTRY BY
HIS MAJESTY'S STATIONERY OFFICE
LONDON
1946

Photo No. 17. HIROSHIMA. Typical, part below ground, earth-covered, timber framed shelter 300 yds. from the centre of damage, which is to the right. In common with similar but fully sunk shelters, none appeared to have been structurally damaged by the blast. Exposed woodwork was liable to "flashburn." Internal blast probably threw the occupants about, and gamma rays may have caused casualties. See paragraph 40.

Photo No. 18. NAGASAKI. Typical small earth-covered back yard shelter with crude wooden frame, less than 100 yds. from the centre of damage, which is to the right. There was a large number of such shelters, but whereas nearly all those as close as this one had their roofs forced in, only half were damaged at 300 yds., and practically none at half a mile from the centre of damage. See paragraph 41.

AIR WAR AND EMOTIONAL STRESS

Psychological Studies of Bombing and Civilian Defense

Irving L. Janis

The RAND Corporation

First Edition

NEW YORK • TORONTO • LONDON
McGRAW-HILL BOOK COMPANY, INC.
1951

CHAPTER 2
EMOTIONAL IMPACT OF THE A-BOMB

UNPREPAREDNESS OF THE POPULATION

At both Hiroshima and Nagasaki, disaster struck without warning. Whether intended so or not, an extraordinarily high degree of surprise was achieved by both A-bomb attacks. At the two target cities, prior to the bombing, there had been relatively little anxiety about the threat of heavy B-29 raids. When the planes carrying the A-bomb arrived over their targets, the population was almost completely unprepared. At the time, not even a light air raid was expected. People were caught at home, at work, out on the city streets, calmly going about their usual daily affairs.

When the first A-bomb was dropped, on August 6, 1945, very few residents of Hiroshima were inside air-raid shelters. An all-clear signal from a previous alert had sounded less than half an hour earlier and the normal routine of community life had resumed. Shortly after eight in the morning, when the explosion occurred, the working-class population was arriving at the factories and shops. Many workers were still out-of-doors en route to their jobs. The majority of school children, along with some adults from the suburbs, were also outside, hard at work building firebreaks as a defense against possible incendiary raids. Housewives, especially in middle-class families, were at home, preparing breakfast. Only a few minutes later, their flaming charcoal stoves were to create hundreds of local fires, adding to a general conflagration of such intensity that even if the assiduous labor of Hiroshima's school children had been completed, the fire storm still would have been beyond control.

At Nagasaki, three days later, the populace had heard only vague reports about the Hiroshima disaster. Here again, people were at

work in factories and offices, tending their homes, engaging in their normal daily activities. A few hours earlier a raid alert had been canceled; before the raid signal could be repeated, the bomb had already exploded. Only 400 people out of a population of close to a quarter of a million were inside the excellent tunnel shelters that could have protected some 75,000 people from severe injury or death.

It is generally recognized that the element of surprise was an important factor contributing to the unprecedented casualty rates at Hiroshima and Nagasaki. Many of those who were exposed to lethal gamma radiation, struck down by flying debris, or trapped in collapsed buildings would not have been killed if they had been warned in time to flee to the outskirts of the city or if they had been in adequate shelters. Thousands of people who were out-of-doors or standing in front of windows would have been protected from incapacitating flash burns if they had been under any sort of cover.[1]

Whether or not they suffered severe injury, those who survived the explosion were also affected by the element of surprise in quite another way. The absence of warning and the generally unprepared state of the population undoubtedly augmented the emotional effects of the disaster. "I was just utterly surprised and amazed and awed." This brief remark, by a newspaper reporter who was living in Nagasaki at the time of the disaster, epitomizes the way in which survivors described the terrifying events to which they were so suddenly exposed.

Of great importance in the predispositional set of the population is the fact that there was not a state of readiness to face danger or to cope with the harsh exigencies of a major catastrophe. The stage was well set for extreme emotional responses to dominate the action. It is against this background of psychological unpreparedness that the emotional impact resulting from the atomic disasters should be viewed.

---

[1] USSBS Report, *The Effects of Atomic Bombs on Hiroshima and Nagasaki,* U.S. Government Printing Office, Washington, D.C., 1946.

Time from flash to blast = 4 sec at 1 mile:

Although exceedingly brief, this time interval was apparently sufficient for executing some forms of protective action.

A substantial proportion of the respondents in Hiroshima and Nagasaki reported having reacted immediately to the intense flash alone, as though it were a well-known danger signal, despite the fact that they were unaware of its significance at the time. A number of them said that they voluntarily ducked down or "hit the ground" as soon as the flash occurred and had already reached the prone position before the blast swept over them. A Nagasaki housewife told about being suddenly frightened by "something shining in the sky" as she was entering her home; she managed to run into her bedroom "to hide" before the blast wave reached the house and shattered all the windows. A worker in Nagasaki reported that he was out in the street waiting for a streetcar when the big "flash-like electric spark" occurred; he promptly dashed into a nearby public shelter and was inside by the time the blast wave struck. These examples indicate that the atomic flash was not merely an impressive visual stimulus but also, in some cases at least, a danger signal evoking semi-automatic overt responses. The examples culled from the interviews serve to amplify one of the incidental observations mentioned in the USSBS medical report: "Japanese claim that in some instances persons were able to shield their faces with their hands between the time the flash was seen and the time the heat wave reached them."[8]

In the instances cited so far, the prompt action proved to be of a highly adaptive character in that it minimized exposure to the secondary heat and blast waves, preventing burns and concussive blows. The interviews also indicate that this was not always the case. The opportunity to minimize the danger was sometimes missed because the individual remained fixed, staring at the place where he saw the flash, or because the prompt action proved to be wholly in-

---

[7] Los Alamos Scientific Laboratory, *The Effects of Atomic Weapons*, U.S. Government Printing Office, Washington, D.C., 1950.

[8] USSBS Report, *The Effects of Atomic Bombs on Health and Medical Services in Hiroshima and Nagasaki*, U.S. Government Printing Office, Washington, D.C., 1947.

appropriate. The following is an example of the latter type of nonadaptive behavior: A young woman in Nagasaki stated that "when I saw the flash of light in the sky I thought it was an incendiary so I started running around looking for water to put it out." It was in the midst of this futile activity that the concussion wave arrived and bombarded her with flying debris.

From the above discussion, it is apparent that some of the survivors immediately perceived the flash as a danger signal. It also appears that for those who were not located near the center there was an opportunity to take protective action that could reduce injuries from the secondary heat wave and from flying glass, falling debris, and other blast effects. It is noteworthy that some survivors evidently failed to make use of this opportunity, as is to be expected when there has been no prior preparation for it.

In a later chapter on the problems of civil defense, we shall have occasion to take account of these findings, since they suggest that casualties in an A-bomb attack might be reduced if the population has been well prepared in advance to react appropriately to the flash of the explosion.

Under such conditions, rapid, uninterrupted flight would generally be the most adaptive response. In the absence of precise, detailed observations of escape behavior, one cannot make an adequate evaluation of the degree of emotional control exhibited by the survivors. To stop and to attempt to extricate others in the face of a rapidly spreading conflagration would sometimes be tantamount to futile sacrifice of one's own life. We cannot be sure, therefore, that those who fled without stopping to help others were behaving impulsively, since we cannot exclude the possibility that they may have been acting on the basis of a realistic appraisal of the danger situation. Our information is too incompletè to permit any fine judgments to be made; from what little is available, it would be unwarranted to conclude that there was a sizeable frequency of inappropriate, negligent, or asocial behavior merely because some instances of abandonment have been reported.

Although Hersey's case material offers little support for the notion that overt panic states were widely prevalent at Hiroshima, it does suggest that under certain local hazardous circumstances, when a large number of people were crowded together, there may have been outbreaks of excited, disorganized group behavior with antisocial consequences. One clear-cut instance of this kind is mentioned by Hersey:

> As Mr. Tanimoto's men worked, the frightened people in the park pressed closer and closer to the river, and finally the mob began to force some of the unfortunates who were on the very bank into the water. Among those driven into the river and drowned were Mrs. Matsumoto of the Methodist school, and her daughter.[30]

A single reference to disorganized group behavior also occurs in one of the eyewitness accounts from Nagasaki: A child who was seven years old at the time of the disaster reports that there was "almost a panic" among the adults in a neighborhood shelter when planes flew over on the night after the bombing.

> The ones near the entrance started pushing to get inside more. They shouted, "Get inside! Move back farther! Let us in, there'll

[30] Hersey, *op. cit.*

> be another flash!" They were so scared! And the ones inside yelled when they got squeezed, because their burns hurt. [Satoru Fukabori's story in *We of Nagasaki*][31]

It should be mentioned that these two incidents are the only examples of group panic or near-panic that were found after a thorough search of all published accounts of the atomic disasters. All the original USSBS interviews from Hiroshima and Nagasaki were also examined. No indications that would suggest the occurrence of mass panic behavior were found in those interviews. A sizeable proportion of the A-bombed survivors do mention that they ran away from the burning city after the explosion, but, in the sparse accounts of themselves and of the people whom they saw, there are no references to excited, uncontrolled behavior that could be characterized as overt "panic."

In only a handful of cases, out of more than a hundred interviewed, is there any allusion to distraught or impulsive behavior that had occurred at least momentarily. The four most extreme examples have already been quoted under "Fear and Terror Reactions," page 21. To these, only a few more could be added, all of which involve only momentary impulsive actions that were immediately brought under control. For example, one woman said that she had been so frightened by the blast that she had already run out of her destroyed house before realizing that her children were left behind, whereupon she immediately returned to the ruins and rescued them.

In contrast to the high percentage of respondents who reported having experienced feelings of fear, less than 10 per cent referred to any action carried out "without knowing what I was doing" or to any other kind of behavior that might remotely imply temporarily disorganized activity.

Obviously, the above negative evidence with respect to panic behavior cannot be taken at face value. There is no way of knowing to what extent the respondents were distorting, suppressing, or repressing their memories of the actual events of the disaster. Since no direct questions were asked about overt actions, some of the

---

[31] Nagai, *op. cit.*

number of psychiatric patients admitted to hospitals and clinics, nor was there any increase in the incidence of suicides or alcoholic intoxication. For most indicators of mental disorder, the statistics show a decrease rather than an increase. For example, cases of attempted suicide among women (recorded by the police in England and Wales) decreased by 32 per cent during the year of the air blitz (1941), as compared with the prewar rate. Figures on juvenile delinquency, on the other hand, registered a rise during the war years, but, according to Titmuss, these data are not a suitable index of either juvenile or adult neurosis.

The findings cited by the various British writers are based on material obtained from a large number of psychiatrists and medical psychologists, including observers with widely different clinical and theoretical approaches to psychiatric problems. Their methods of investigation ranged from brief psychiatric examinations for purposes of large-scale statistical tabulation to intensive case studies of small groups of patients. Despite the diversity of diagnostic criteria used, there is high agreement that the type of air attacks to which London and other English cities were subjected during World War II did not produce a sizeable increase in major psychiatric disorders.

The available information on psychiatric air-raid casualties among German civilians is consistent with the British findings. At the end of the war in Europe, the Medical Team of the USSBS sent a questionnaire to German psychiatrists and directors of psychiatric institutions. The "universal reply" to the questionnaire was that "neither organic neurologic diseases nor psychiatric disorders can be attributed to nor are they conditioned by, the air attacks."[8]

A parallel survey of relevant specialists on psychosomatic disorders in Germany revealed some definite wartime trends (which will be discussed later in this chapter), but what is relevant here is the general conclusion: ". . . in view of the tremendous exogenous stimuli which offered a fertile ground for the development of psychosomatic complaints, the relative infrequency of the development

[8] USSBS Report, *The Effect of Bombing on Health and Medical Care in Germany*, U.S. Government Printing Office, Washington, D.C., 1945.

admissions for diseases of the nervous system. The statistics from several cities suggest that during periods of bombing there may have been a slight increase in the number of cases with organic and functional psychosis, but this trend is not consistently borne out. Detailed results are presented from only two psychiatric hospitals. One of the hospitals, in Yokohama, showed that there was a *marked increase* in the number of admissions for schizophrenia, general paresis, and other psychoses during May, 1945, the month during which the city received its most severe bombing. The other psychiatric hospital, in Kobe, showed that during the months of severe bombing attacks there was a *decline* in the number of admissions for psychosis and for all other neuropsychiatric disorders. Although some of the Japanese hospital statistics lend themselves to interpretations about possible causal factors, the evidence is not adequate for ascertaining whether bombing produced any significant changes in the incidence of neuropsychiatric cases. In general, the statistical data from Japan do not contradict the observations reported from England and Germany.

The absence of psychiatric casualties following the one air raid on American territory—the Pearl Harbor attack on December 7, 1941—has been described by Weatherby.[11] On the day of the attack, no patients with war neurosis were brought to the hospital that normally served a majority of American troops stationed at Oahu. During the two weeks following the attack, the number of psychiatric admissions was no greater than during the two weeks preceding the attack.

In evaluating the evidence on psychiatric effects of air warfare, it is necessary to recognize that the information is far from complete and that many of the observations are unsystematic and impressionistic in character. Moreover, the statistical studies of psychiatric casualty rates have been criticized on various grounds as underestimating the actual number of psychiatric casualties to be expected among a civilian population exposed to heavy air raids. Vernon[12]

---

[11] F. E. Weatherby, "War Neuroses after Air Attack on Oahu, Territory of Hawaii, Dec. 7, 1941," *War Med.*, Vol. 4, 1943, pp. 270–271.

[12] *Loc. cit.*

If the population of a target city is unprotected, the vast majority would undergo traumatizing experiences of personal involvement in an A-bomb attack. It should be recognized, therefore, that the adequacy of civil defense preparations designed to increase the physical safety of the population have a direct bearing on the emotional impact of an atomic disaster. If a target city cannot be warned and evacuated before an attack is launched, if the residents cannot reach adequate shelters, and if well-trained civil defense teams are not available to carry out the essential operations of disaster control, the devastating consequences cannot be counted solely in terms of the inordinate toll of dead and injured people. The less adequate the physical protection of the population, the higher the incidence of emotional shock and disorganized behavior. In an atomic war, such reactions on a mass scale might become a crucial deterrent to national recovery.[3]

To a very large extent, the *morale* of the survivors of an A-bomb attack will be determined by the effectiveness of civil defense measures. During the air blitz against England it became increasingly apparent that the availability of welfare and relief facilities can play a decisive role in minimizing feelings of bitterness, suspicion, free-floating hostility, and other adverse morale effects.

> The rest centres, the feeding schemes, the casualty services, the compensation grants, and the whole apparatus of the post-raid services both official and voluntary occupied this role of absorbing shock. They took the edge off the calamaties of damage and destruction; they could not prevent, but they helped to reduce, a great deal of distress. Like the civil defence services, these schemes encourage people to feel that they were not forgotten. They render much less likely (in William James' phrase) an "unguaranteed existence," with all its anxieties, its corruptions and its psychological maladies.[4]

---

[3] The reassurance value and morale-building effects of various military defense measures are greatly in need of detailed study. It should be clear to the reader that the present study has not gone into military plans for active and passive defense of potential targets.

[4] R. M. Titmuss, *Problems of Social Policy.* His Majesty's Stationery Office, London, 1950.

not very useful to assume that "panic" will necessarily be the most probable response.

"Panic" is often used by both popular writers and social scientists as a colorful term to designate any collective dread that is judged to be inappropriate to the occasion. For example, the reactions following the *Invasion from Mars* radio program, which are commonly referred to as panic, consisted mainly of the following: Many people, having tuned in during the middle of the program, heard newscasts and announcements to the effect that some sort of invasion had occurred and that evacuation was necessary; they immediately felt anxious, notified others in their vicinity, phoned members of their families, and in some cases went so far as to carry out the instructions to evacuate.[7] Evidently there were relatively few in the radio audience whose behavior could be characterized as manifestly irrational or antisocial. For most participants, the panic consisted primarily in their reacting to a *false* emergency warning in a manner which, by and large, would have been appropriate for a *genuine* emergency warning, without first checking on its authenticity.

Although "panic" is an extremely ambiguous term, the image it usually brings to mind is that of a wildly excited crowd behaving in an impulsive, completely disorganized fashion, each person abandoning all social values in a desperate effort to save himself. From the available literature on extreme fear reactions, it appears that this sort of behavior rarely occurs unless (1) there is an obvious physical danger which is immediately present (e.g., a raging fire only a few feet away) and (2) there are no apparent routes of escape. Hence, panic, in the limited sense of the term, is likely to be evoked by an A-bomb attack primarily in the area where the disaster actually occurs, e.g., among those who are trapped by the general conflagration within the city. In places which are not affected by the explosion, including the cities which are potential targets for the next attack, there is far less danger of a serious outbreak of overt panic. That is to say, there is a strong likelihood that with appropriate psychological preparation such reactions can be prevented.

[7] H. Cantril, *The Invasion from Mars,* Princeton University Press, Princeton, N.J., 1940.

the Federal Civil Defense agency should have responsibility for releasing basic information and that state and local defense officials should develop an intensive educational program for their own areas.

It can be assumed, therefore, that as part of the general preparedness program there will be some form of educational program on atomic warfare devised to reach the American public. Thus, while one sector of the general population will be receiving intensive special training for the type of civilian defense functions discussed in the preceding chapter, the remainder of the population will also be receiving instruction designed to prepare them to cope with A-bomb emergencies.

OBJECTIVES OF A PUBLIC EDUCATIONAL PROGRAM

That there will be enormous problems involved in attempting to carry out a successful program of mass education becomes apparent as soon as one considers the quantity and the content of the elementary material to be learned. The following is a brief outline of typical items of information which would be essential for the average civilian to know if he is to maximize his chances for survival following an atomic explosion:

1. Appropriate actions during an A-bomb alert: the best place to go if one is at home, at work, out in the open; the best position of the body for protection against blast effects; etc.
2. Appropriate emergency responses to the bright flash of an A-bomb explosion in case of a surprise attack: what the flash will look like; how to avoid injury from the secondary heat wave and the concussion wave; what to do immediately after the concussion wave has passed.
3. Ways of averting fire hazards: how to escape from burning buildings; what to do if one's clothes catch fire; where the safest places of refuge are if one is caught inside the fire area; how the potential fire hazard can be reduced if one

is at the periphery of the explosion; under what conditions one should evacuate to escape from a developing conflagration.

4. Essential precautions against radiological hazards: how to tell whether or not one should remain indoors; how to find an uncontaminated area; which kinds of food are safe to eat and which are unsafe; decontamination rules concerning removal of exposed clothing, scrubbing of exposed parts of the body, etc.
5. Probable location of emergency facilities: nearest medical-aid station if at home or at work; where food, clothing, shelter, and supplies can be obtained after escaping from the disaster area.

The above items pertain only to *individual* survival. If the average person is to be adequately prepared to give the most elementary kind of aid to members of his family and to others, there are many more topics to be included—such as, how to extract a person from beneath debris without injuring him unnecessarily; how to carry injured persons; how to give emergency first aid for burns, cuts, broken bones.

Certain kinds of technical information might also be included. For instance, in order to reduce confusion about the large number of "do's" and "don'ts" concerning radiological hazards—and to prevent the undesirable extremes of irrational indifference and excessive fear—it will probably be helpful to give some basic information about the nature of the radioactivity emitted by an A-bomb explosion. Perhaps by presenting the material pictorially and graphically, so as to reify the radioactive particles, people will come to regard them as a familiar and real part of the physical world. Conceivably, this material might be supplemented by training in certain types of technical "know-how."

It may turn out to be feasible to mass-produce various kinds of radiological safety equipment at a relatively low cost: detection meters, film badges to register total amount of personal exposure, gas masks or respirators, canvas suits and boots, etc.

~~RESTRICTED~~ For PRO 9/7/89

3 OCTOBER 1963

HOME OFFICE

SCIENTIFIC ADVISER'S BRANCH

CD/SA 116

RESEARCH ON BLAST EFFECTS IN TUNNELS

With Special Reference to the Use of London Tubes as Shelter

by F. H. Pavry

Summary and Conclusions

The use of the London tube railways as shelter from nuclear weapons raises many problems, and considerable discussion of some aspects has taken place from time to time. But - until the results of the research here described were available - no one was able to say with any certainty whether the tubes would provide relatively safe shelter or not.

This research, consisting of a series of model experiments, has demonstrated that the risk from blast in the tubes would be less than the risks above ground. The results are considered to be consistent enough to provide a good estimate of full-scale conditions, and reliable enough to be used as a basis for Home Office shelter policy regarding the London tube railways.

Introduction

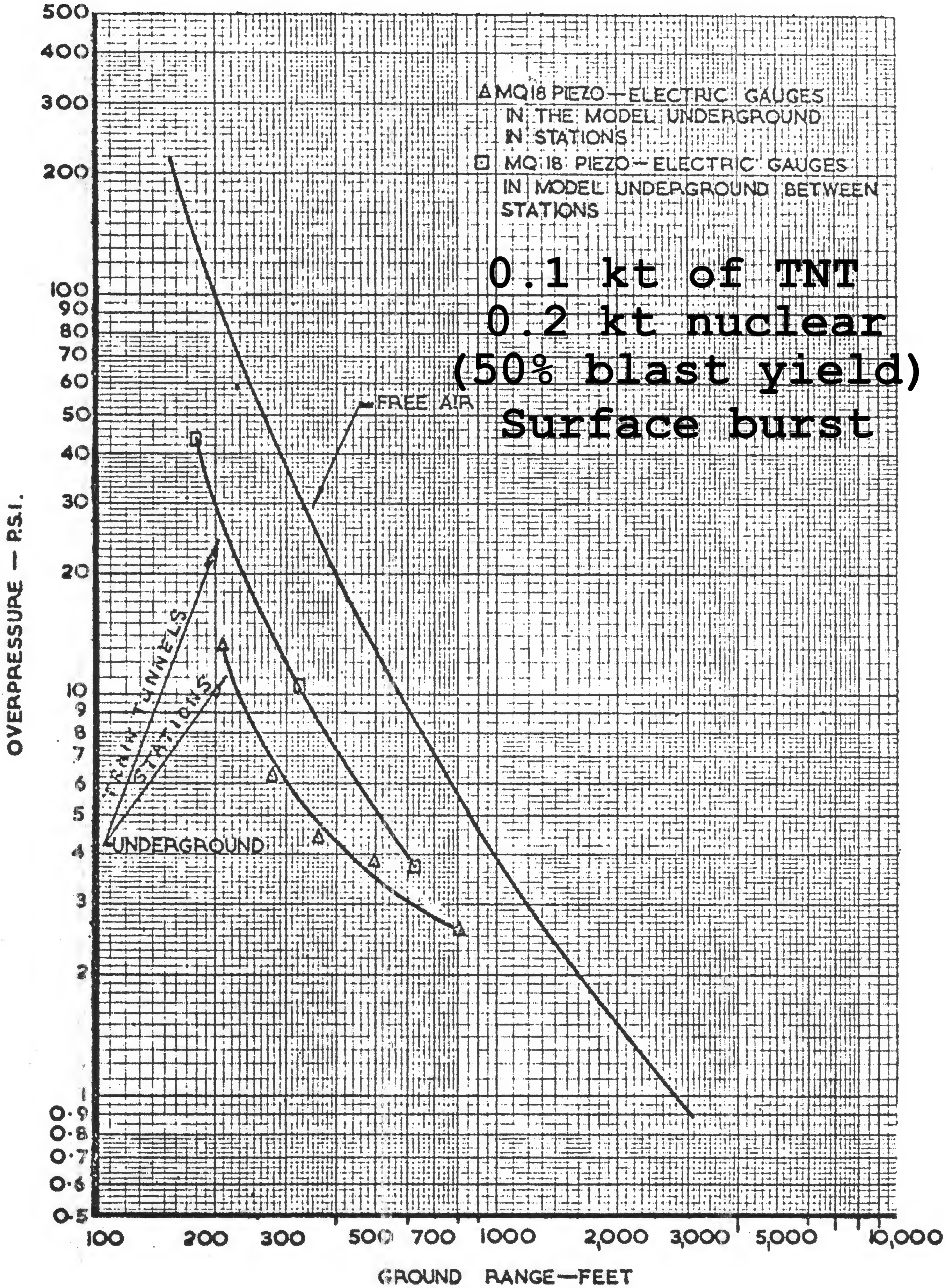
When the Advisory Group on Structural Research for Civil Defence was formed in 1957, the Chairman recommended that a study of the effects of blast on tunnels should be one of the main research projects. The relevant paragraphs of his proposals(1) for a research programme were:-

"In any consideration of tunnels as shelter the crucial problem is the entry of blast, either through existing openings or from a crater formed by a ground-burst bomb. It is particularly important to know if the collapse of a tunnel by earth shock would prevent the blast from entering it, and also whether the collapse would provide a seal against the entry of water from the crater. It is probable that some data could be derived from model experiments using H.E. charges. But it is for consideration whether the results would be so conclusive that the behaviour of full-size tunnels when damaged by megaton weapons could be forecast with the confidence that a major shelter programme would demand."

At the second meeting(2) the Group agreed that model experiments with H.E. charges would be worthwhile, and that the Atomic Weapons Research Establishment (A.W.R.E.) should carry out this research, which has now been accepted by the Advisory Group as successfully completed. A summary record of the progress follows.

RESTRICTED

100 ton TNT test on 1000 ft section of London Underground tube at Suffield, Alberta, 3 Aug 1961



Atomic Weapons Research Establishment, "1/40th Scale Experiment to Assess the Effect of Nuclear Blast on the London Underground System", Report AWRE-E2/62, 1962, Figure 30. (National Archives ES 3/57.)

These trials are described in a preliminary report[5] prepared for the Advisory Group by A.W.R.E. It was shown that the blast pressure inside a tunnel system, having openings at intervals to ground level, is less than the pressure at ground level at any distance from the explosion, by a factor of about 3. This reduction in pressure was apparently caused by the station entrances acting as expansion chambers. This observation was of outstanding significance to the consideration of London tubes as shelter.

All previous research on blast in tunnels - and a great amount of work was done on this in the last war - had been conducted with blast entering the open end of a tunnel without side openings. This research had shown that the blast, once it had got into a tunnel, tended to travel great distances without appreciable diminution. This had, therefore, led to the general belief that the London tubes could be death traps rather than shelters.

The more recent research here described showed for the first time that a person sheltering in a tube would be exposed to a blast pressure only about $\frac{1}{3}$ as great as he would be exposed to if he was above ground. (In addition, of course, he would be fully protected from fallout in the tube.)

In fact A.W.R.E. carried out two further tests, with more accurate scaling of station volumes based on more detailed information from the London Transport Executive. A full report on all four tests is in preparation.

These later tests showed that the pressure in station tunnels was only about 1/6th of the ground-level pressure, but that the reduction was not so great in the smaller-diameter train tunnels.

At this stage the Advisory Group were reasonably satisfied that this problem - of blast entry from stations - had been solved. But the other major question of blast entry direct from the crater remained in doubt, on account of the very small scale of the tests to date. Therefore, when the opportunity arose of testing at a really large scale at Suffield, Canada, it was naturally accepted.

<u>Large-Scale Field Test (1/40) at Suffield, Alberta</u>

The test is fully described in an A.W.R.E. report[6]. The decision of the Canadian Defence Research Board to explode very large amounts of high explosive provided a medium for a variety of target-response trials that was welcome at a time when nuclear tests in Australia were suspended. A.W.R.E. used the 100-ton explosion in 1961 to test, among other items, the model length of the London tube, at 1/40th scale, that had already been tested at 1/117 scale.

<u>Blast Entry from Stations</u>

There was remarkable agreement with the 1/117th scale trials: "maximum overpressure in the train tunnels was of the order of $\frac{1}{3}$rd the corresponding peak shock overpressure in the incident blast. The pressures in the stations were about 1/6th those in the corresponding incident blast .... ". In comparing the results at the two scales it was noted that the pressures in the train tunnels (between stations) was higher at Suffield than at the smaller scale; this may, the report suggests, have been due to some blast entry from the crater at Suffield.

Blast Entry from the Crater

There may - as has just been noted - have been some entry of blast at the crater. But the all-important fact is that it was nowhere enough to bring the pressure in the tunnel up to more than a $\frac{1}{3}$rd of the free-air pressure (see fig. 30 reproduced, and attached to this note.) From this, and from a detailed study of tunnel rings ejected by the explosion over a wide area, it can be concluded that the instantaneous crushing of the tube near the crater sealed it against the entry of any significant blast pressure.

Air Flow in Stations

The Report indicates that there would be turbulence generated by blast entry at stations and that there would be a danger to occupants there, on account of blast "windage" acting on them and on missiles that could injure them. This danger would be less in the train tunnels between stations.

Conclusion

The Advisory Group discussed the Suffield Test on tunnels on Nov. 1st 1962, and concluded that model experiments have successfully demonstrated that the risks from blast inside the London tubes would be less than above ground. The Group considered that the results obtained were consistent enough to provide as good an estimate of full-scale effects from megaton weapons as was likely to be obtainable, and that the Chairman could advise the Home Office confidently on the basis of these results. The Group accepted that there would be a risk of casualty-producing air flow in stations, but decided to defer a decision on whether further research on this problem would be profitable. The Chairman said that he would first convey the results of the completed research to the Shelter Division of the Home Office before asking the Group whether it was worth studying this remaining, but less important, problem.

3rd October, 1963.

References

(1) Advisory Group on Structural Research for Civil Defence

Note by Chairman on the Structural Research Programme for Shelters. SAB/SG(57)6. (Restricted)

(2) Notes of Meeting on 15th May 1957. SAB/SG(57)2nd Minutes (Confidential)

(3) The Entry of Air Blast from Craters into Tunnels. A.W.R.E. Report E1/59 (Official Use Only)

(4) The Effect of Tunnel Blockage on Shock Waves .... SAB/SG(58)6 (Confidential)

(5) Model Experiments on the Entry of Blast into the London Underground System, Interim Report on Rounds 1 and 2. SAB/SG(59)4 (Confidential)

(6) 1/40th Scale Experiment to Assess the Effect of Nuclear Blast on the London Underground System. A.W.R.E. Report E2/62. (Official Use Only.)

Proceedings of the Symposium
held at Washington, D. C.
April 19-23, 1965 by the
Subcommittee on Protective Structures,
Advisory Committee on Civil Defense,
National Academy of Sciences—
National Research Council

Protective Structures

for

CIVILIAN POPULATIONS

1966

MODEL ANALYSIS

Mr. Ivor Ll. DAVIES
Suffield Experimental Station
Canadian Defense Research Board
Ralston, Alberta, Canada

Nuclear-Weapon Tests

In 1952 we fired our first nuclear device, effectively a "nominal" weapon, at Monte Bello, off northwest Australia. To the blast loading from this weapon we exposed a number of reinforced-concrete cubicle structures that had been designed for the dynamic loading conditions, and for which we made the best analysis of response we were competent to make at that time. Our estimates of effects were really a dismal failure. The structures were placed at pressure levels of 30, 10, and 6 psi, where we expected them to be destroyed, heavily damaged with some petaling of the front face, and extensively cracked, respectively. In fact, the front face of the cubicle at 30 psi was broken inwards; failure had occurred along both diagonals, and the four triangular petals had been pushed in. At the 10-psi level, where we had three cubicles, each with a different wall thickness (6, 9, and 12 in.), we observed only light cracking in the front face of that cubicle with the least thick wall (6 in.). The other two structures were apparently undamaged, as was the single structure at the 6-psi level.

In 1957, the first proposals were made for the construction of the underground car park in Hyde Park in London. The Home Office was interested in this project since, in an emergency, the structure could be used as a shelter. Consequently a request was made to us at Atomic Weapons Research Establishment (A.W.R.E.) to design a structure that would be resistant to a blast loading of about 50 psi, and to test our design on the model scale.

Using the various load-deformation curves obtained in this test, an estimate was made of the response of the structure to blast loading. Of particular interest was the possible effect of 100 tons of TNT, the first 100-ton trial at Suffield in Alberta.

10 p.s.i.

34 p.s.i.

Dynamic tests, Monte Bello cubicles.

A total of seven more models was made; six were shipped to Canada and placed with the top surface of the roof flush with the ground and at positions where peak pressures of 100, 80, 70, 60, 50, and 40 psi were expected. The seventh model was kept in England for static testing at about the time of firing. The results were not as expected. In the field, the four models farthest from the charge were apparantly undamaged; we could see no cracking with the eye, nor did soaking the models with water reveal more than a few hair cracks. The model nearest the charge was lightly cracked in the roof panels and beams, and one of the columns showed slight spalling at the head. This model had been exposed to a peak pressure of 110 psi.

BLAST AND OTHER THREATS

Harold Brode
The RAND Corporation, Santa Monica, California

Chemical High-Explosive Weapons

As in past aerial warfare, bombs and missiles carrying chemical explosives to targets are capable of extensive damage only when delivered in large numbers and with high accuracy.

Biological Warfare

Most biological agents are inexpensive to produce; their effective dissemination over hostile territories remains the chief deterrent to their effective employment. Twenty square miles is about the area that can be effectively covered by a single aircraft; large area coverage presents a task for vast fleets of fairly vulnerable planes flying tight patterns at modest or low altitudes. While agents vary in virulence and in their biologic decay rate, most are quite perishable in normal open-air environments. Since shelter and simple prophylactic measures can be quite effective against biological agents, there is less likelihood of the use of biological warfare on a wholesale basis against a nation, and more chance of limited employment on population concentrations —perhaps by covert delivery, since shelters with adequate filtering could insure rather complete protection to those inside.

Chemical Weapons

Chemical weapons, like biological weapons, are relatively inexpensive to create, but face nearly insurmountable logistics problems on delivery. Although chemical agents produce casualties more rapidly, the greater amounts of material to deliver seriously limit the likelihood of their large-scale deployment. Furthermore, chemical research does not hold promise of the development of significantly more toxic chemicals for future use.

Radiological Weapons

The advantages of such modifications are much less real than apparent. In all weapons delivered by missiles, minimizing the payload and total weight is very important. If the total payload is not to be increased, then the inclusion of inert material to be activated by neutrons must lead to reductions in the explosive yield. If all the weight is devoted to nuclear explosives, then more fission-fragment activity can be created, and it is the net difference in activity that must be balanced against the loss of explosive yield. As it turns out, a fission explosion is a most efficient generator of activity, and greater total doses are not achieved by injecting special inert materials to be activated.

The Neutron Bomb

The neutron bomb, so called because of the deliberate effort to maximize the effectiveness of the neutrons, would necessarily be limited to rather small yields—yields at which the neutron absorption in air does not reduce the doses to a point at which blast and thermal effects are dominant. The use of small yields against large-area targets again runs into the delivery problems faced by chemical agents and explosives, and larger yields in fewer packages pose a less stringent problem for delivery systems in most applications. In the unlikely event that an enemy desired to minimize blast and thermal damage and to create little local fallout but still kill the populace, it would be necessary to use large numbers of carefully placed neutron-producing weapons burst high enough to avoid blast damage on the ground, but low enough to get the neutrons down. In this case, however, adequate radiation shielding for the people would leave the city unscathed and demonstrate the attack to be futile.

The thermal radiation from a surface burst is expected to be less than half of that from an air burst, both because the radiating fireball surface is truncated and because the hot interior is partially quenched by the megatons of injected crater material.

SUPERSEISMIC GROUND-SHOCK MAXIMA (AT 5-FT DEPTH)

Vertical acceleration: $\alpha_{vm} \simeq 340\,\Delta P_s/C_L$ ± 30 per cent. Here acceleration is measured in g's and overpressure (ΔP_s) in pounds per square inch. An empirical refinement requires C_L to be defined as the seismic velocity (in feet per second) for rock, but as three fourths of the seismic velocity for soil.

OUTRUNNING GROUND-SHOCK MAXIMA (AT ~10-FT DEPTH)

Vertical acceleration: $\alpha_{vm} \simeq 2 \times 10^5/C_L r^2$ + factor 4 or -factor 2. Acceleration is measured in g's, and r is the scaled radial distance—i.e., $r = R/W^{1/3}$ kft/(mt)$^{1/3}$.

Data taken on a low air-burst shot in Nevada indicate an exponential decay of maximum displacement with depth. For the particular case of a burst of ~ 40 kt at 700 ft, some measurements were made as deep as 200 ft below the surface of Frenchman Flat, a dry lake bed, which led to the following approximate decay law, according to Perret.

$\delta = \delta_0 \exp(-0.017D)$,

where δ represents the maximum vertical displacement induced at depth D, δ_0 is the maximum displacement at the surface, and D is the depth in feet.

Perret, W.R., Ground Motion Studies at High Incident Overpressure, The Sandia Corporation, Operation PLUMBBOB, WT-1405, for Defense Atomic Support Agency Field Command, June 1960.

THE PROTECTION AGAINST FALLOUT RADIATION AFFORDED BY CORE SHELTERS IN A TYPICAL BRITISH HOUSE

Daniel T. Jones
Scientific Adviser, Home Office, London

Protective Factors in a Sample of British Houses (Windows Blocked)

Protective Factor	Percentage of Houses
< 25	36%
25-39	28%
40-100	29%
> 100	7%

"A very much improved protection could be obtained by constructing a shelter core. This means a small, thick-walled shelter built preferably inside the fallout room itself, in which to spend the first critical hours when the radiation from fallout would be most dangerous."(1)

The full-scale experiments were carried out at the Civil Defense School at Falfield Park.(2)

In the staircase construction, the shelter consisted of the cupboard under the stairs, sandbags being placed on treads above and at the sides.

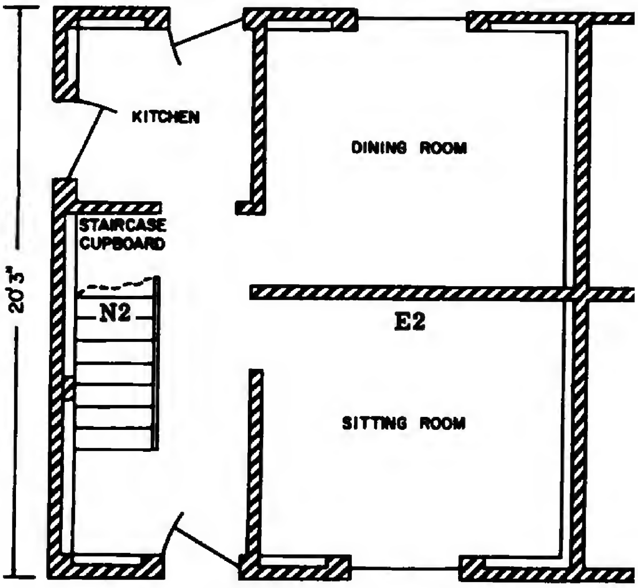
A 93 curies cobalt-60 source was used.

9 in. brick walls The windows and doors were not blocked	Position	contribution r/hr/c/ft^2 Ground	Roof	Protective Factor
House only	E2	15.0	8.4	21
Lean-to	E2	10.4	2.4	39
Staircase cupboard:				
Stairs only sandbagged	N2	29.2	5.3	14
Stairs and outer wall sandbagged	N2	16.4	4.6	24
Stairs, outer wall, kitchen wall and corridor partition sandbagged	N2	8.8	1.8	47

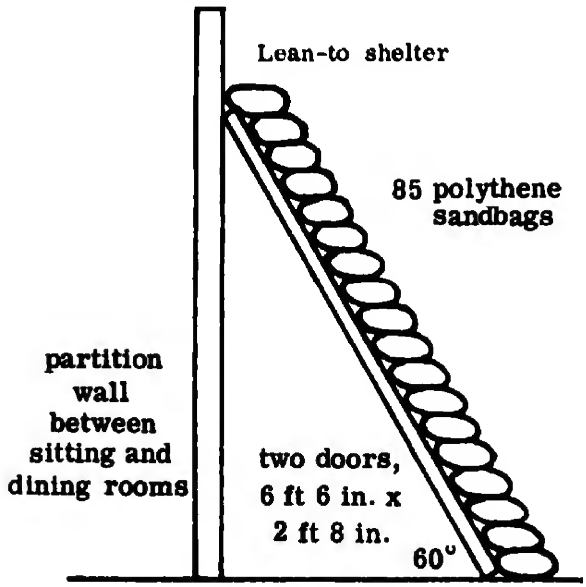
1. Civil Defence Handbook No. 10, HMSO, 1963.

2. Perryman, A. D., Home Office Report CD/SA 117.

1. Six sandbags per tread, and a double layer on the small top landing. 96 sandbags were used.
2. As (1), together with a 4-ft-high wall of sandbags along the external north wall. 160 sandbags were used.
3. As (2), together with 4-ft-high walls of sandbags along the kitchen/cupboard partition wall and along the passage partition. 220 sandbags were used.



sandbags 24 in. x 12 in. when empty; 16 in. x 9 in. x 4 in. when filled with 25 lb of sand.



floor area 21 sq ft.

Foreword

If the country were ever faced with an immediate threat of nuclear war, a copy of this booklet would be distributed to every household as part of a public information campaign which would include announcements on television and radio and in the press. The booklet has been designed for free and general distribution in that event. It is being placed on sale now for those who wish to know what they would be advised to do at such a time.

May 1980

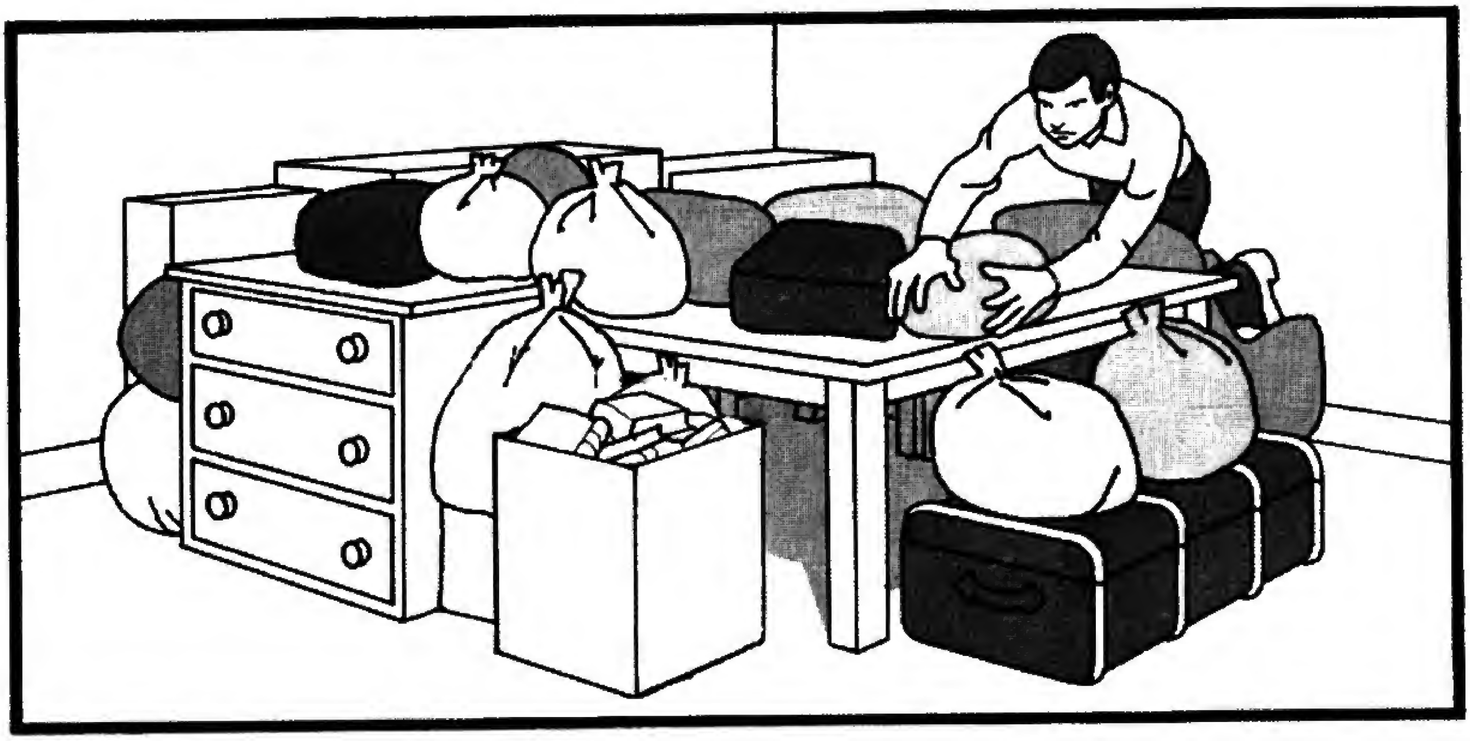
Protect and Survive
ISBN 0 11 3407289

If Britain is attacked by nuclear bombs or by missiles, we do not know what targets will be chosen or how severe the assault will be.

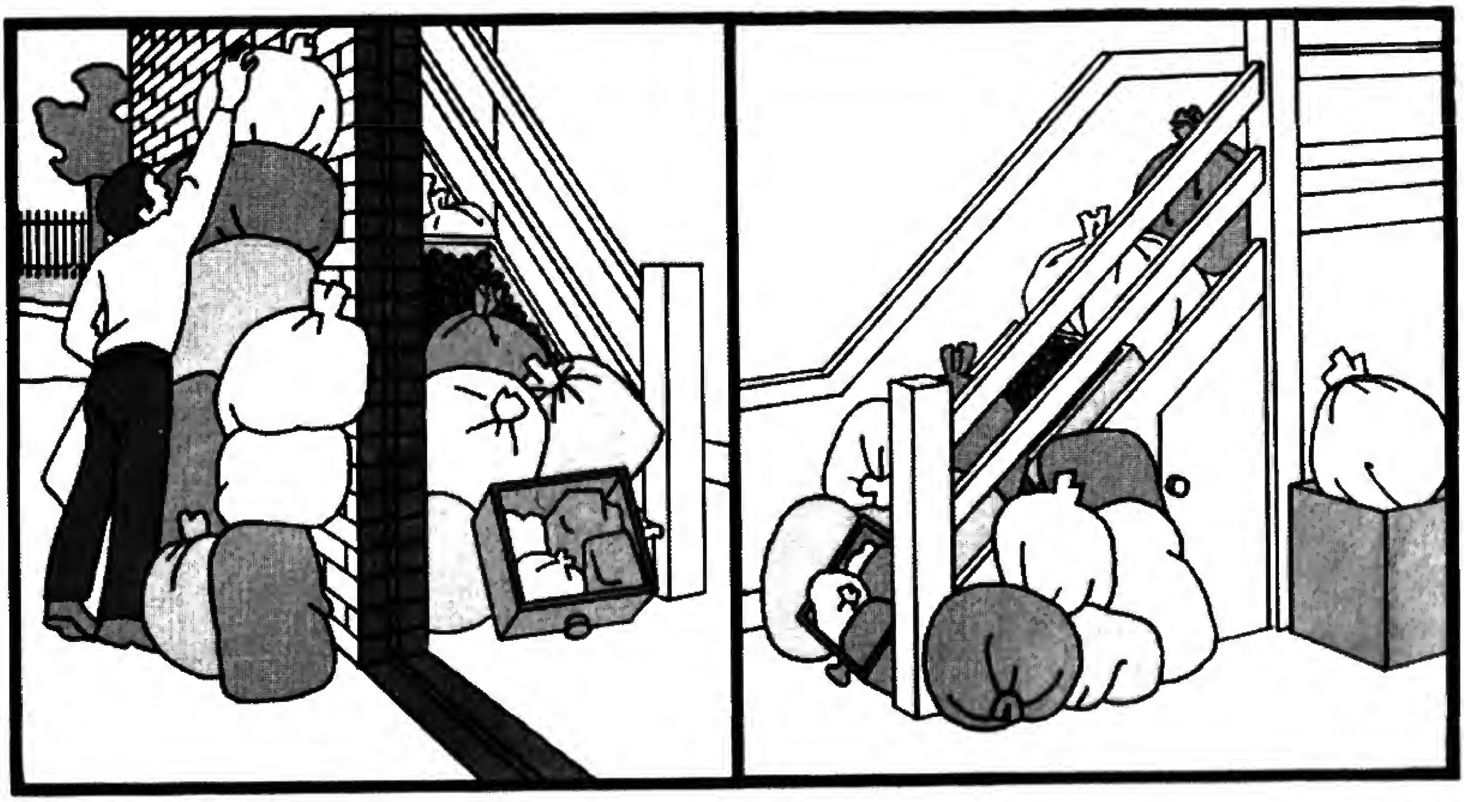
If nuclear weapons are used on a large scale, those of us living in the country areas might be exposed to as great a risk as those in the towns. The radioactive dust, falling where the wind blows it, will bring the most widespread dangers of all. No part of the United Kingdom can be considered safe from both the direct effects of the weapons and the resultant fall-out.

The dangers which you and your family will face in this situation can be reduced if you do as this booklet describes.

Use tables if they are large enough to provide you all with shelter. Surround them and cover them with heavy furniture filled with sand, earth, books or clothing.



Use the cupboard under the stairs if it is in your fall-out room. Put bags of earth or sand on the stairs and along the wall of the cupboard. If the stairs are on an outside wall, strengthen the wall outside in the same way to a height of six feet.



What to do after the Attack:

After a nuclear attack, there will be a short period before fall-out starts to descend. Use this time to do essential tasks. This is what you should do.

Do not smoke.

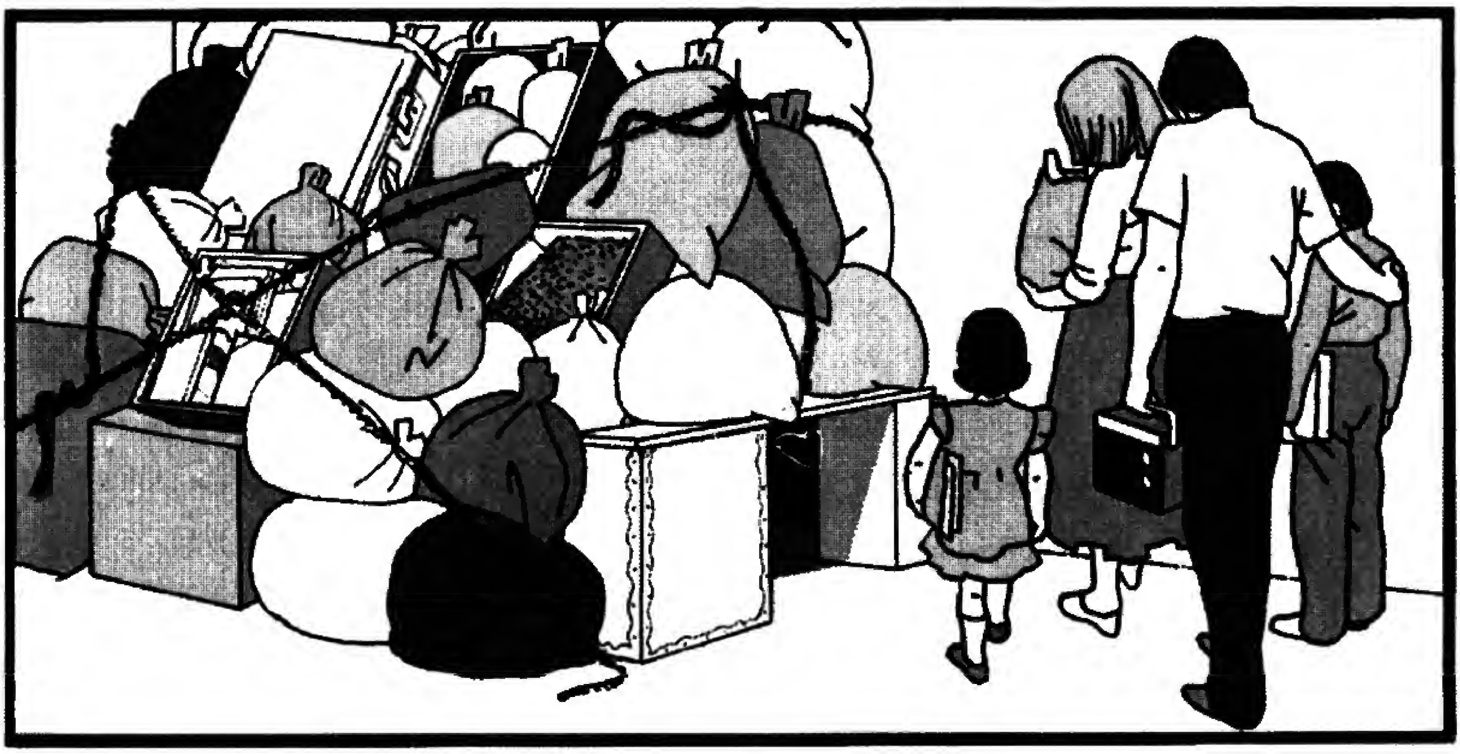
Check that gas, electricity and other fuel supplies and all pilot lights *are* turned off.

Go round the house and put out any small fires using mains water if you can.

If anyone's clothing catches fire, lay them on the floor and roll them in a blanket, rug or thick coat.

If there is structural damage from the attack you may have some time before a fall-out warning to do minor jobs to keep out the weather – using curtains or sheets to cover broken windows or holes.

If you are out of doors, take the nearest and best available cover as quickly as possible, wiping all the dust you can from your skin and clothing at the entrance to the building in which you shelter.



HOME OFFICE

SCOTTISH HOME DEPARTMENT

MANUAL OF CIVIL DEFENCE

Volume I

PAMPHLET No. 1

NUCLEAR WEAPONS

LONDON

HER MAJESTY'S STATIONERY OFFICE

1956

30 Research into the causes of fire in Hiroshima and Nagasaki, combined with a study of the secondary fire risk from the flying bomb damage in this country during the last war has shown that with nuclear attack the secondary fire risk is likely to be small compared with the primary risk of direct ignition by thermal radiation.

Fire precautions

31 Although the fire risk even from a nominal bomb is always serious, targets in this country, where the great majority of buildings are of brick, stone or concrete, are less vulnerable to fire than were those in Japan, where most of the buildings were of wood.

32 since the thermal radiation has no great penetrating power, any opaque screen, especially a white one, will keep it out:

33 Another obvious fire precaution is the removal of all readily combustible material from the direct path of any heat radiation that could possibly enter windows or other openings.

34 Both these precautions apply only to those windows and other openings that have a direct view of some part of the sky.

The probable fire situation in a British city

35 Japanese houses are constructed of wood and once they were set on fire they continued to burn even when knocked over. In this country only about 10 per cent. of all the material in the average house is combustible, and under conditions of complete collapse, where air would be almost entirely excluded, it is doubtful whether a fire could continue on any vigorous scale.

38 The Hiroshima bomb (but not the Nagasaki one) caused a fire storm. A fire storm occurred in Hamburg and possibly also in several other German cities as a result of accurate and very dense attacks with incendiary and high explosive bombs by the R.A.F. Information on the subject is limited, but it has been fairly well established that during these particular raids on Germany half the buildings in the target area were set on fire in about half an hour. In such circumstances it seems that nothing can prevent all the fires from joining together into one mass fire engulfing the whole area.

40 It seems unlikely from the evidence available that an initial density of fires equivalent to one in every other building would be started by a nuclear explosion over a British city. Studies have shown that a much smaller proportion of buildings than this would be exposed to thermal radiation and even then it is not certain that continuing fires would develop. Curtains may catch fire, but it does not necessarily follow that they will set light to the room; in the last war it was found that only one incendiary bomb out of every six that hit buildings started a continuing fire.

From a 10 megaton bomb, with its longer lasting thermal radiation (see paragraph 21), it takes about 20 calories per square centimetre to start fires because so much of the heat (spread out over the longer emission) is wasted by conduction into the interior of the combustible material and by convection and re-radiation whilst the

temperature of the surface is being raised to the ignition point. But the distance at which 20 calories per square centimetre can be produced is only 11 miles, so that the scaling factor for a 10 megaton airburst bomb is therefore 11 and not 22.

43 For a ground burst bomb, however, several other factors contribute to a further reduction in the fire range. Apart from an actual loss of heat by absorption into the ground and from the pronounced shielding effect of buildings, the debris from the crater tends to reduce the radiating temperature of the fireball and a greater proportion of the energy is consequently radiated in the infra red region of the spectrum —this proportion being more easily absorbed by the atmosphere.

44 An important point in relation to personal protection against the effects of hydrogen bomb explosions is that because the thermal radiation lasts so long there is more time for people who may be caught in the open, and who may be well beyond the range of serious danger from blast, to rush to cover and so escape some part of the exposure. For example, people in the open might receive second degree burns (blistering) on exposed skin at a range of 16 miles from a 10 megaton ground burst bomb (8×2—see paragraph 24). If, however, they could take cover in a few seconds they would escape this damage. Moreover, at this range the blast wave would not arrive for another minute and a half so that any effects due to the blast in the open (e.g. flying glass, etc.) could be completely avoided.

DOMESTIC NUCLEAR SHELTERS

TECHNICAL GUIDANCE

A HOME OFFICE GUIDE

Government bookshops
49 High Holborn, London WC1V 6HB
13a Castle Street, Edinburgh EH2 3AR
41 The Hayes, Cardiff CF1 1JW
Brazennose Street, Manchester M60 8AS
Southey House, Wine Street, Bristol BS1 2BQ
258 Broad Street, Birmingham B1 2HE
80 Chichester Street, Belfast BT1 4JY

Government publications are also available through booksellers

Prepared by the Home Office and the Central Office of Information 1981
Printed in England for Her Majesty's Stationery Office by Hobbs the Printers of Southampton

ISBN 0 11 340777 7 (2462) Dd717557 C40 1/82 G381

Introduction

This manual of technical guidance on the design of domestic nuclear shelters has been prepared by a working group set up by the Emergency Services Division of the Home Office. The working group was asked to consider designs of nuclear shelters which could be made available to members of the public in the United Kingdom who might wish to purchase and install shelters for the use of themselves and their families.

The working group realised that the range of designs which it might produce would not be exhaustive. However, it was aware of the need to give technical guidance to professional engineers to assist them in producing reliable shelter designs. Thus the first three chapters of this book are written to give such guidance.

The other four chapters of the book give detailed designs of five shelters. These five cover a range of types which are applicable to different sorts of houses; they also cover a wide price range. These designs are not intended to be exhaustive, and as explained in the text, the working group is already giving attention to other designs, particularly those which might be incorporated into existing or new houses and also underground shelters of shapes other than box-like and using materials other than concrete. It is planned to publish details of this work at a later date.

The members of the working group are:

Mr J C Cotterill, *Chairman*	Scientific Advisory Branch, Home Office
Dr J R Stealey	Scientific Advisory Branch, Home Office
Mr A Lindfield	Scientific Advisory Branch, Home Office
Mr K A Day	F6 Division, Home Office
Mr R W T Haines, C Eng	Directorate of Works, Home Office
Mr H G S Banks, C Eng	Directorate of Works, Home Office
Mr M Connell, C Eng	Directorate of Civil Engineering Services Property Services Agency, Department of Environment
Mr S Bell, C Eng	Directorate of Civil Engineering Services Property Services Agency, Department of Environment
Mr S England, C Eng	Directorate of Mechanical and Electrical Engineering Services Property Services Agency, Department of Environment
Mr I Leys	Atomic Weapons Research Establishment, Ministry of Defence Foulness
Major I C T Ingall	HQ United Kingdom Land Forces Wilton, Wilts.
Mr R Million, *Secretary*	F6 Division, Home Office

Any enquiries concerning this manual should be addressed to the Home Office, F6 Division, and not to individual members of the working group.

To obtain some protection from the heat it is necessary to move out of the direct path of the rays from the fireball; any kind of shade will be of some value.

A fire-storm occurred only in an area of several square miles, heavily built up with buildings containing plenty of combustible material and where at least every other building in the area had been set alight. It is not considered that the initial density of fires, equivalent to one in every other building, would be caused by a nuclear explosion over a British city. Studies have shown that due to shielding, a much smaller proportion of buildings than this would be exposed to the heat flash. Moreover, the buildings in the centres of most British cities are now more fire-resistant and more widely spaced than they were 30 to 40 years ago. This low risk of fire-storms would be reduced still further by the control of small initial and secondary fires.

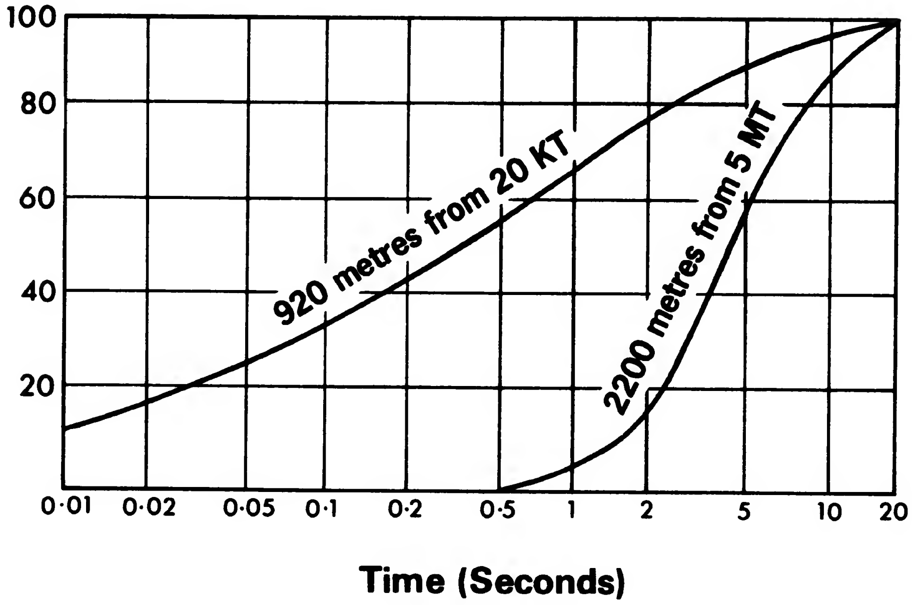
Fig. 8 ***Half-value thicknesses of shielding materials***

	Against INR mm	Against INR (inches)	Against fallout radiation mm	Against fallout radiation (inches)
Steel	38	(1.5)	18	(0.7)
Concrete	152	(6.0)	56	(2.2)
Earth	190	(7.5)	84	(3.3)
Water	330	(13.0)	122	(4.8)
Brickwork	157	(6.2)	71	(2.8)

The amount of scattering of initial gamma radiation depends upon a number of factors, but probably amounts to about 10 per cent of that in the main beam.

Fig. 9 gives the percentage of initial gamma radiation dose received as a function of time for 20 KT and 5 MT air bursts. It can be seen that in the former case about 65 per cent and in the latter case 5 per cent of the total initial gamma radiation dose is received during the first second. In the case of the higher yield weapon it can be seen that if some shelter could be obtained within one second of seeing the explosion flash, such as by falling prone behind some substantial object, it could make the difference between life and death. Such an action would also help to prevent the translational effect of the blast.

Fig. 9 *Percentage of total initial gamma dose received*



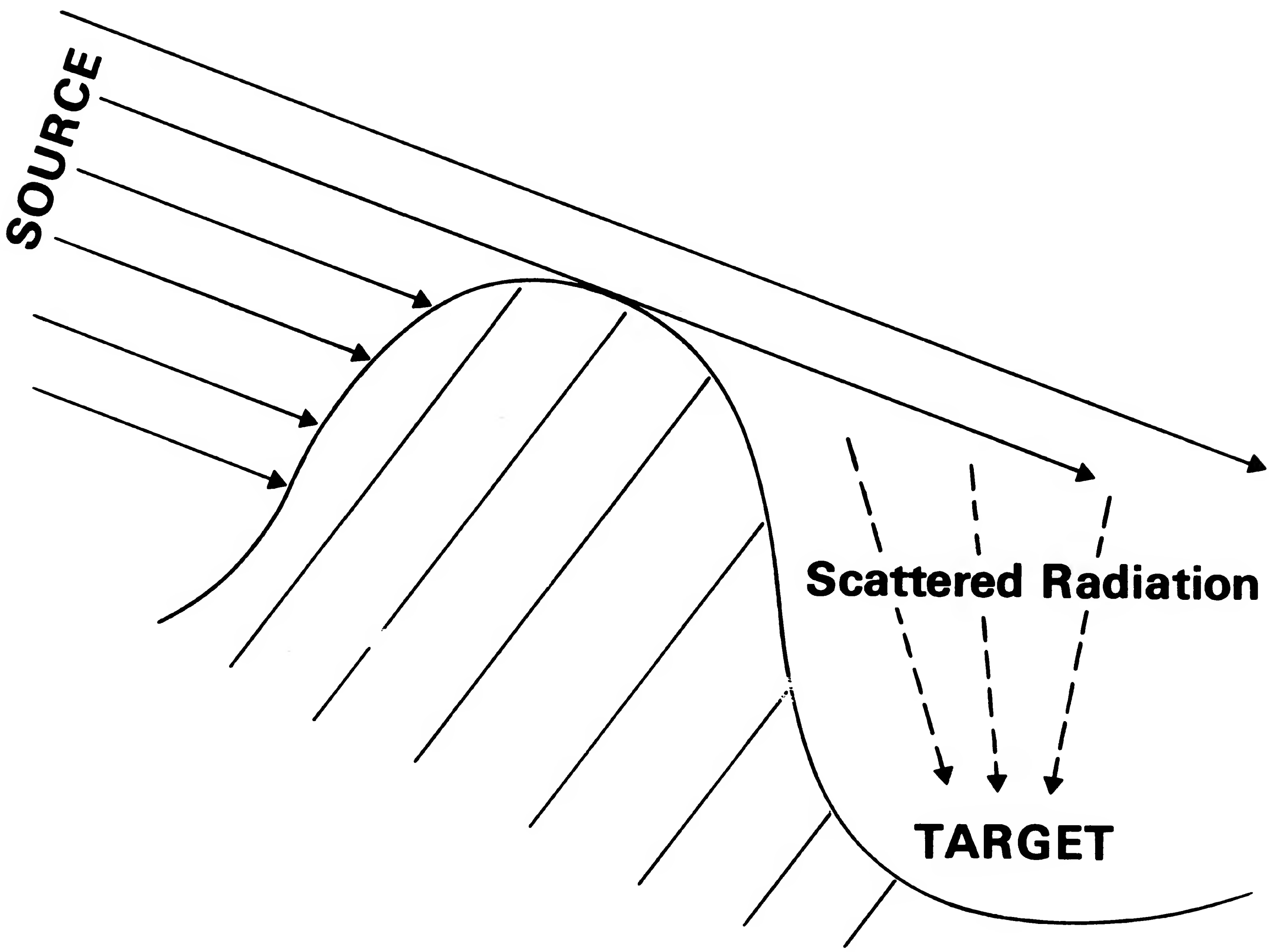


Fig. 10 *Target exposed to scattered gamma radiation from a nuclear burst*

Further comments on protection against INR and fallout radiation

Fig. 12 gives a comparison of the protective factors against INR gamma, neutrons and fallout radiation of some typical buildings. The data has been taken from *Effects of Nuclear Weapons* and the choice has been made of those buildings which are reasonably comparable with structures in the UK. The wide range of values is due partly to uncertainty in the data (since some have been calculated and others derived from weapons trials) and partly to the fact that protection to some extent is determined by the position in the building where the protective factor is measured.

Fig. 12 ***Protective factors of various buildings against initial gamma, neutron and fallout gamma radiation***

Structure	Initial gamma	Neutrons	Fallout gamma
1 metre underground	250–500	100–500	5000
Shelter partly above ground: with 600 mm earth 900 mm earth	 15–35 50–150	 12–50 20–100	 50–200 200–1000

Summary of effects of nuclear weapons

From this brief review of the effects of nuclear weapons we can list the order of events from the detonation of a weapon. These are:

(a) Light and heat flash – immediate, and lasting some seconds.

(c) Blast wave – following from about a half second to several seconds after the light and heat flash.

(d) Fires – these may have been ignited by the heat flash

(e) Fallout – about one half hour to several hours after burst.

Considerations arising from the probable attack pattern

In section 1.1.1 reference was made to the fact that an expected attack pattern on the United Kingdom might use 200 megatons on about 80 targets. If we now make an assumption that this attack would be in the form of 100 weapons of 1 MT airbursts and 100 weapons of 1 MT groundbursts we can use the information given in Fig. 6 to indicate the probability of areas being subject to various effects.

On this assumption, we should find that about 2.2 per cent of the land area of the UK would be subject to overpressures in the 'A' ring of 77 kPa (11 psi) and above about 1.8 per cent would be subject to overpressures of between 42 and 77 kPa (6-11 psi) in the 'B' ring and about 10 per cent of the land area would be subject to overpressures of between 10 and 42 kPa (1.5 to 6 psi). The rest of the land area, about 85 per cent, would be subject to blast in the D ring of 5 to 10 kPa (0.75 to 1.5 psi) or to no blast at all. Blast effects in the D ring will cause minor damage to buildings and no lethalities.

SEPTEMBER 1964

HOME OFFICE

CD/SA 121

SCIENTIFIC ADVISER'S BRANCH

IGNITION AND FIRE SPREAD IN URBAN AREAS FOLLOWING A NUCLEAR ATTACK

G. R. Stanbury

INITIAL FIRE INCIDENCE

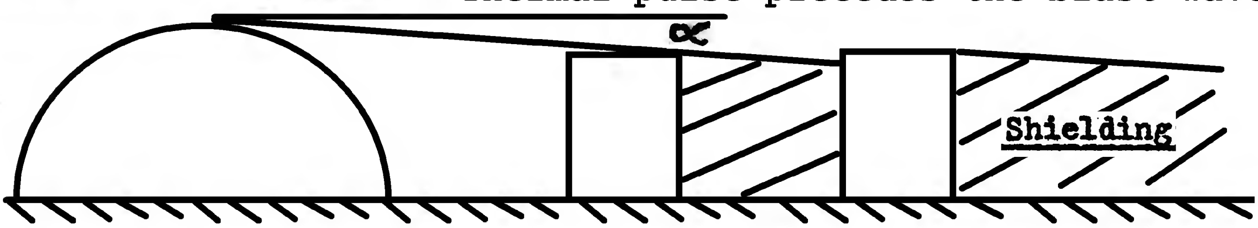
For a 1 MT groundburst bomb the height of the top of the fireball above ground is about 0.72 miles. Because this distance is large compared with the height of most buildings, the exposed upper floors do actually see a large part of the fireball and not just the top of it, but in assuming that the radiation is just as intense from the top as from the middle we were overestimating the fire risk.

On the above basis the following table gives the number of exposed upper floors (to the nearest ½ floor) for a range of distances from the explosion and a range of street widths.

Effect of Shielding: Estimation of the number of exposed floors

Assuming that buildings on opposite sides of a street which is receiving heat radiation from a direction perpendicular to its length are of the same height

Thermal pulse precedes the blast wave



Distance from explosion miles	Angle of arrival α°	$\tan\alpha$	Width of street (units of 10 ft.)						
			2	3	4	5	6	7	8
1	35	.72	1.5	2	3	3.5	4.5	5	6
1½	26	.48	1	1.5	2	2.5	3	3.5	4
2	20	.36	.5	1	1.5	2	2	2.5	3
3	13½	.24	.5	.5	1	1	1.5	1.5	2
4	10	.18	.5	.5	.5	1	1	1.5	1.5
5	8	.15	.5	.5	.5	.5	1	1	1

we take the average depth of a floor to be 10 ft.

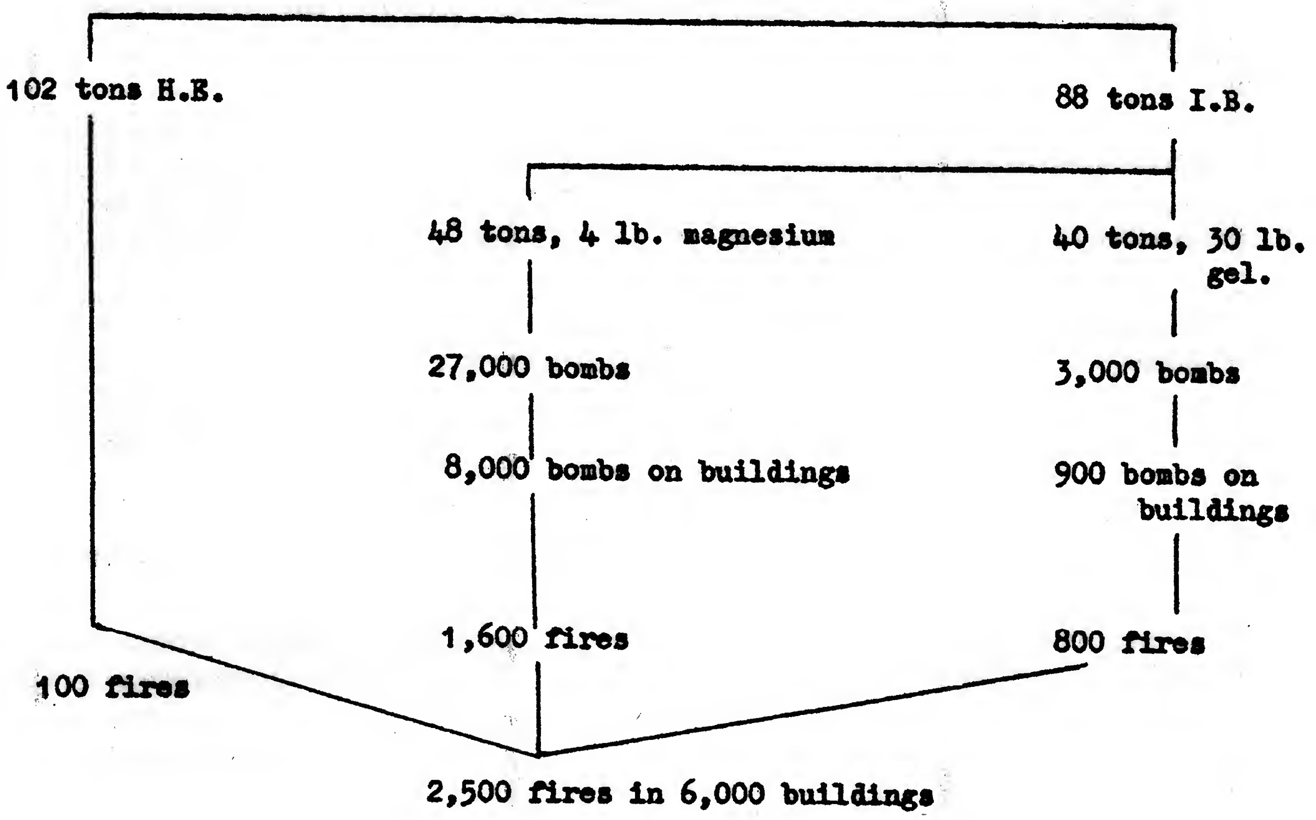
Angle between heat flash and street (degrees)	90-75	75-60	60-45	45-30	30-15	15-0
Proportion of heat flash entering windows %	99	92.5	80	60	40	14

SPREAD OF FIRE

From last war experience of mass fire raids in Germany it was concluded that the overall spread factor was about 2; i.e. about twice as many buildings were destroyed by fire as were actually set alight by incendiary bombs

Number of fires started per square mile in the fire-storm raid on Hamburg, 27th/28th July, 1943

Bombs dropped



However, the important thing to note is that the total number of fires started in each square mile (2,500) was nearly half that of the total number of buildings; in other words, almost every other building was set on fire during the raid itself. When this happened no fire-fighting organisation, however efficient could hope to prevent the fires from joining together and engulfing the whole area.

When the figure of 1 in 2 for the German fire storms is compared with the figures for initial fire incidence of $\sim$ 1 in 15 to 30 obtained in the Birmingham and Liverpool studies it can only be concluded that a nuclear explosion could not possibly produce a fire storm.

Fire situation from 1,499 fly bombs in the built-up part of the London Region

WWII V1 high explosives (1 ton TNT warhead) (cruise missiles)

Where dropped	Number of fly bombs	Fly Bombs Caused				
		No fire	Small fire	Medium fire	Serious fire	Major fire
City	~~199~~ 119	47	49	17	4	2
West-End	33	8	22	2	-	1
Closed Residential	430	207	203	20	-	-
Open Residential	804	478	296	28	2	-
Docks	113	64	39	8	1	1
Grand Totals	1,499	804	609	75	7	4

Discussion of results

Two important points emerge from a study of these results:-

(i) The small proportion of fly bombs - less than 20% - which started fires of any greater category than "small" even in the most heavily built-up areas; and

(ii) The large proportion which started no fires at all even in the most heavily built-up areas.

All these fly bombs fell in the summer months of 1944 which were unusually dry. In winter in this country in residential areas there are many open fires which may provide extra sources of ignition. The domestic occupancy is a low fire risk however, and as the proportion of such property in the important City and West End areas is small this should not introduce any serious error. Moreover, in winter, the high atmospheric humidity and the correspondingly high moisture content of timber would tend to retard or even prevent the growth of fire.

In order to determine how many fly bombs are equivalent to one nominal atomic bomb one method is to compare the areas over which a given category of house damage is produced by each. If we do this for a $\frac{3}{8}$th mile air burst as at Hiroshima, the result is that 1 atomic bomb does as much damage as about 1,200 fly bombs.

This in itself is not a serious fire situation and it is doubtful whether it could ever give rise to a fire storm. In Hamburg 2,500 fires were started per square mile by a bomb density (combined H.E. and I.B.) of 200 tons per square mile, and for the area of destruction produced by an atomic bomb this would correspond to a total of about 10,000 fires.

UCRL-TR-231593

LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

Thermal Radiation from Nuclear Detonations in Urban Environments

R. E. Marrs, W. C. Moss, B. Whitlock

June 7, 2007

An obvious next step (left for future work) would be a calculation of burn injuries and fires. Even without shadowing, the location of most of the urban population within buildings causes a substantial reduction in casualties compared to the unshielded estimates. Other investigators have estimated that the reduction in burn injuries may be greater than 90% due to shadowing and the indoor location of most of the population [6].

We have shown that common estimates of weapon effects that calculate a "radius" for thermal radiation are clearly misleading for surface bursts in urban environments. In many cases only a few unshadowed vertical surfaces, a small fraction of the area within a thermal damage radius, receive the expected heat flux.

In future work, our code could be extended to tally the total surface area receiving various amounts of heat, and to account for reflected radiation.

References

1. *The Effects of Nuclear Weapons*, edited by S. Glasstone and P. J. Dolan, U S Dept. of Defense (1977).

2. "RADFLO Physics and Algorithms," E. M. D. Symbalisty, J. Zinn, and R. W. Whitaker, LA-12988-MS (September, 1995).

3. "The Development and Testing of the Air Transport of Radiation Code Version 6 (ATR6)." D. C. Kaul et al., DNA-TR-91-237 (November, 1992).

4. *Handbook of Nuclear Weapon Effects (EM-1)*, J. Northrop, DSWA (1996).

5. http://www.esri.com/

6. L. Davisson and M. Dombroski, private communication; "Radiological and Nuclear Response and Recovery Workshop: Nuclear Weapon Effects in an Urban Environment 2007," M. Dombroski, B. Buddemeier, R. Wheeler, L. Davisson, T. Edmunds, L. Brandt, R. Allen, L. Klennert, and K. Law, UCRL-TR-XXXX (2007), in review.

The Effects of

Nuclear Weapons

SAMUEL GLASSTONE
Editor

Revised Edition
Reprinted February 1964

Prepared by the
UNITED STATES DEPARTMENT OF DEFENSE
Published by the
UNITED STATES ATOMIC ENERGY COMMISSION
April 1962

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C. - Price $3.00 (paper bound)

Foreword

This book is a revision of "The Effects of Nuclear Weapons" which was issued in 1957. It was prepared by the Defense Atomic Support Agency of the Department of Defense in coordination with other cognizant governmental agencies and was published by the U.S. Atomic Energy Commission. Although the complex nature of nuclear weapons effects does not always allow exact evaluation, the conclusions reached herein represent the combined judgment of a number of the most competent scientists working on the problem.

There is a need for widespread public understanding of the best information available on the effects of nuclear weapons. The purpose of this book is to present as accurately as possible, within the limits of national security, a comprehensive summary of this information.

Robert S. McNamara

Secretary of Defense

Glenn T. Seaborg

Chairman
Atomic Energy Commission

Figure 7.33a. Thermal effects on wood-frame house 1 second after explosion (about 25 cal/sq cm).

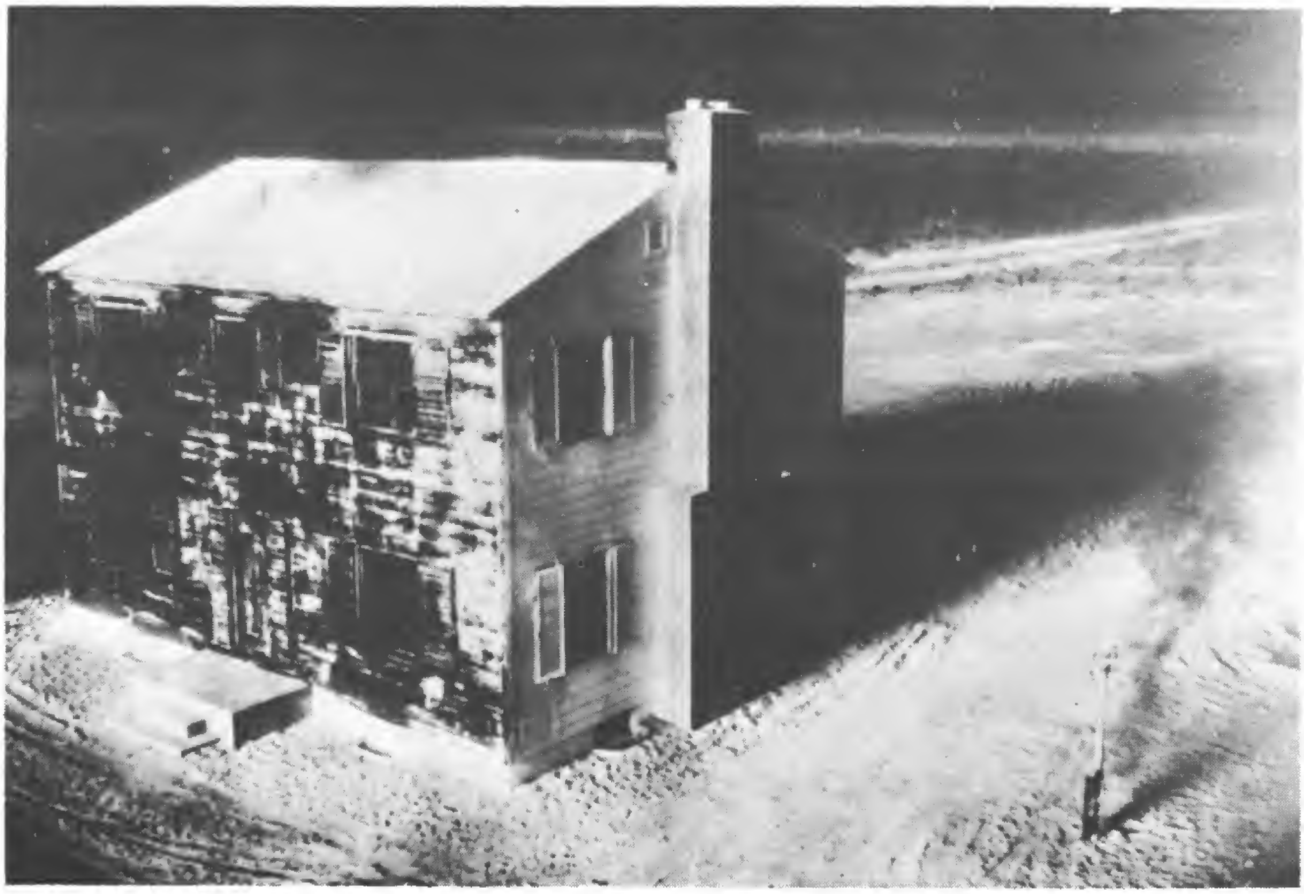


Figure 7.33b. Thermal effects on wood-frame house about ¾ second later.

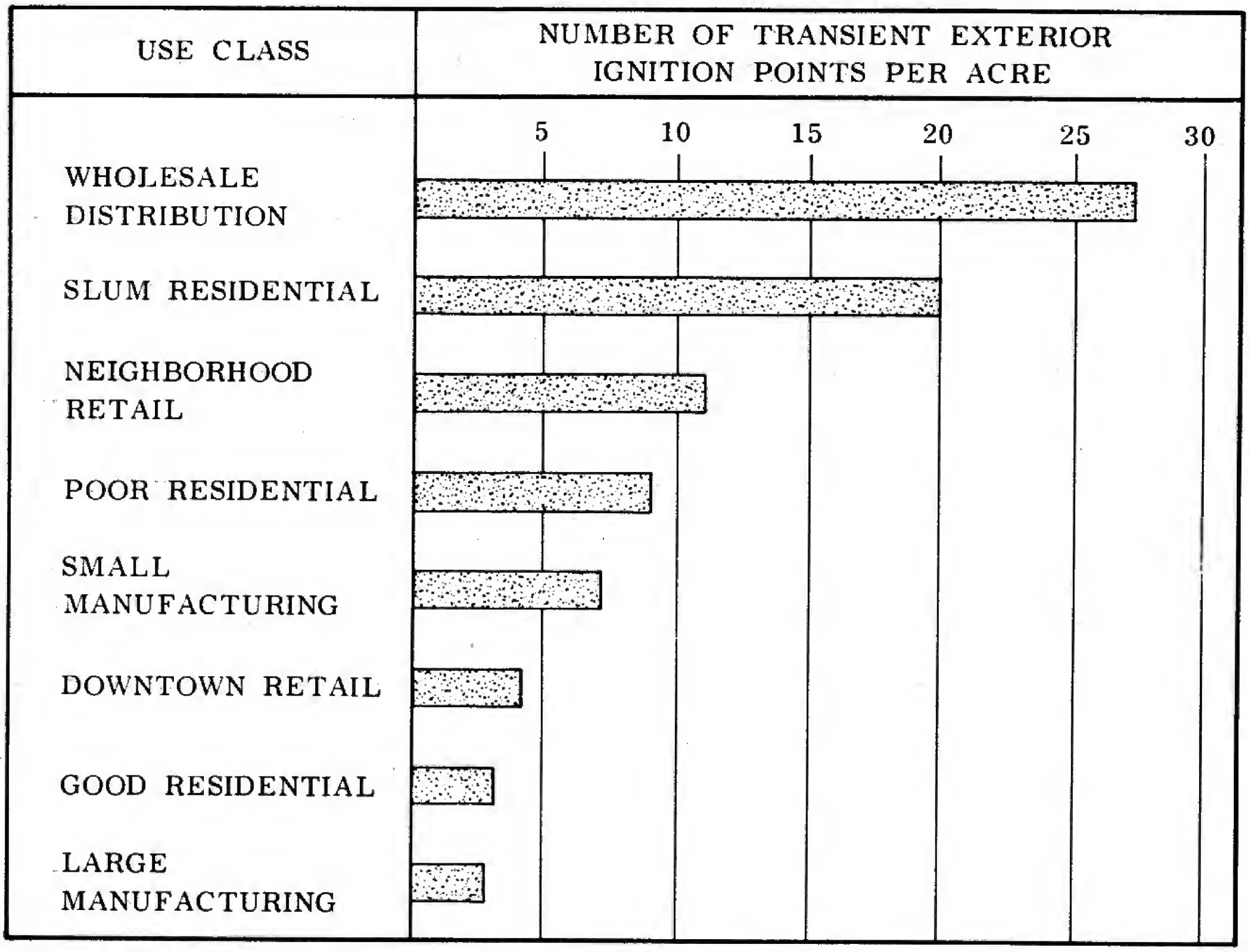


Figure 7.55. Frequency of exterior ignition points for various areas in a city

the formation of a significant fire, capable of spreading, will require appreciable quantities of combustible material close by, and this may not always be available.

7.57 The fact that accumulations of ignitable trash close to a wooden structure represent a real fire hazard was demonstrated at the nuclear tests carried out in Nevada in 1953. In these tests, three miniature wooden houses, each having a yard enclosed with a wooden fence, were exposed to 12 calories per square centimeter of thermal radiation. One house, at the left of Fig. 7.57, had weathered siding showing considerable decay, but the yard was free from trash. The next house also had a clean yard and in addition, the exterior siding was well maintained and painted. In the third house, at the right of the photograph, the siding, which was poorly maintained, was weathered, and the yard was littered with trash.

7.58 The state of the three houses after the explosion is seen in Fig. 7.58. The third house, at the right, soon burst into flame and was burned to the ground. The first house, on the left, did ignite but it did not burst into flame for 15 minutes. The well maintained house in the center with the clean yard suffered scorching only. It is of interest to recall that the wood of a newly erected white-painted

Figure 7.57. Wooden test houses before exposure to a nuclear explosion, Nevada Test Site.

Figure 7.58. Wooden test houses after exposure to a nuclear explosion.

house exposed to about 25 calories per square centimeter was badly charred but did not ignite (see Fig. 7.33b).

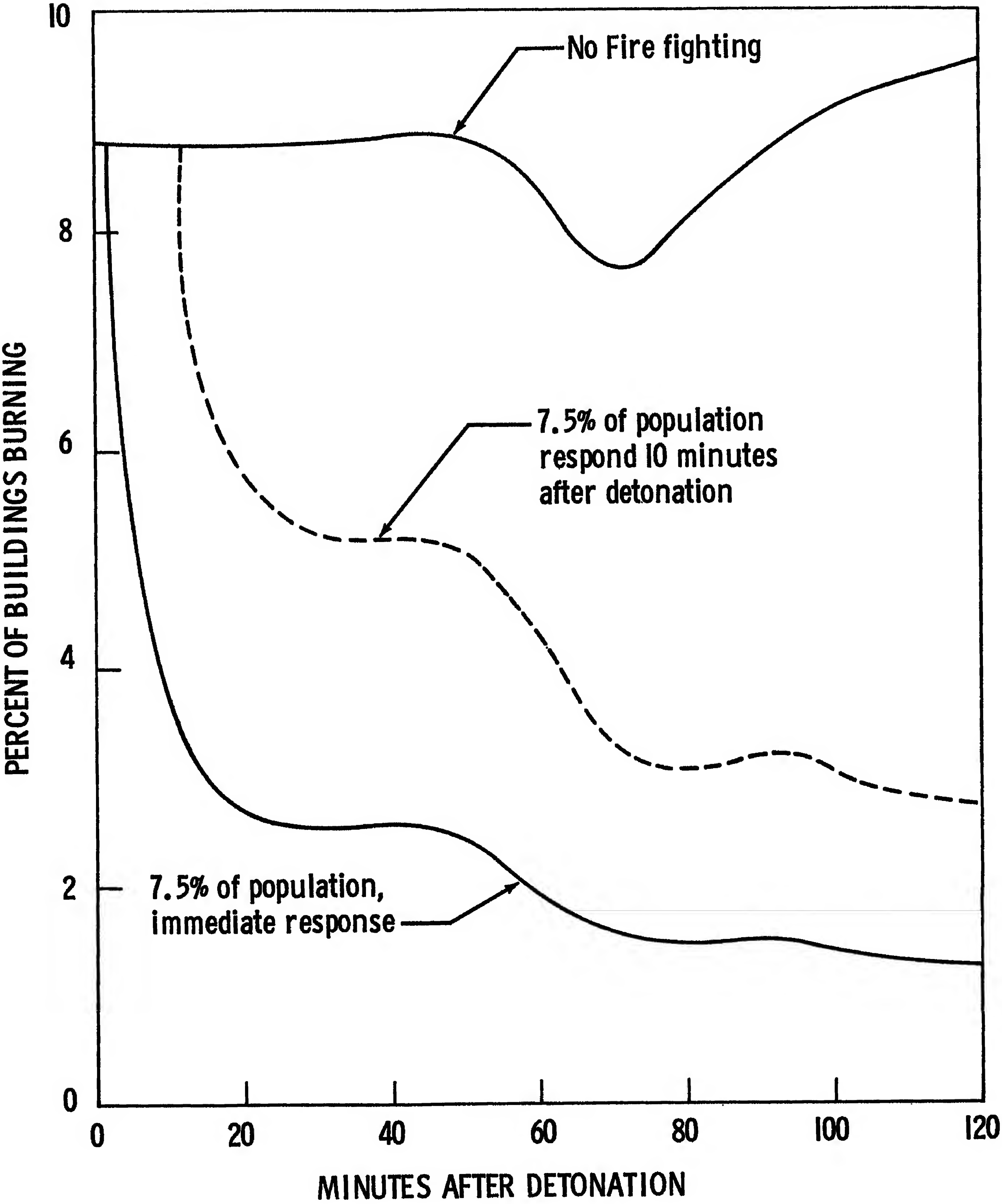
7.59 The value of fire-resistive furnishing in decreasing the number of ignition points was also demonstrated in the tests. Two identical, sturdily constructed houses, each having a window 4 feet by 6 feet facing the point of burst, were erected where the thermal radiation exposure was 17 calories per square centimeter. One of the houses contained rayon drapery, cotton rugs, and clothing, and, as was expected, it burst into flame immediately after the explosion and burned completely. In the other house, the draperies were of vinyl plastic, and rugs and clothing were made of wool. Although much ignition occurred, the recovery party, entering an hour after the explosion, was able to extinguish the fires.

7.76 It should be noted that the fire storm is by no means a special characteristic of nuclear weapons. Similar fire storms have been reported as accompanying large forest fires in the United States, and especially after incendiary bomb attacks in both Germany and Japan during World War II. The high winds are produced largely by the updraft of the heated air over an extensive burning area. They are thus the equivalent, on a very large scale, of the draft of a chimney under which a fire is burning. Because of limited experience, the conditions for the development of fire storms in cities are not well known. It appears, however, that some, although not necessarily all, of the essential requirements are the following: (1) thousands of nearly simultaneous ignitions over an area of at least a square mile, (2) heavy building density, e.g., more than 20 percent of the area is covered by buildings, and (3) little or no ground wind. Based on these criteria, only certain sections—usually the older and slum areas—of a very few cities in the United States would be susceptible to fire storm development.

12.35. The major part of the thermal radiation travels in straight lines, and so any opaque object interposed between the fireball and the exposed skin will give some protection. This is true even if the object is subsequently destroyed by the blast, since the main thermal radiation pulse is over before the arrival of the blast wave.

12.36 At the first indication of a nuclear explosion, by a sudden increase in the general illumination, a person inside a building should immediately fall prone, as described in § 12.30, and, if possible, crawl behind or beneath a table or desk or to a planned vantage point. Even if this action is not taken soon enough to reduce the thermal radiation exposure greatly, it will minimize the displacement effect of the blast wave and provide a partial shield against splintered glass and other flying debris. An individual caught in the open should fall prone to the ground in the same way, while making an effort to shade exposed parts of the body. Getting behind a tree, building, fence, ditch, bank, or any structure which prevents a direct line of sight between the person and the fireball, if possible, will give a major degree of protection. If no substantial object is at hand, the clothed parts of the body should be used to shield parts which are exposed.

Takata, A.N., **Mathematical Modeling of Fire Defenses, IITRI, March 1970, AD 705 388.**



The Effects of

Nuclear Weapons

SAMUEL GLASSTONE
Editor

Prepared by the

UNITED STATES DEPARTMENT OF DEFENSE

Published by the

UNITED STATES ATOMIC ENERGY COMMISSION

June 1957

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. - Price $2.00 (paper bound)

TABLE 3.11

OVERPRESSURE, DYNAMIC PRESSURE, AND WIND VELOCITY IN AIR AT SEA LEVEL

Peak overpressure (pounds per square inch)	*Peak dynamic pressure (pounds per square inch)*	*Maximum wind velocity (miles per hour)*
72	80	1, 170
50	40	940
30	16	670
20	8	470
10	2	290
5	0. 7	160
2	0. 1	70

3.12 At a given location, the dynamic pressure changes with time in a manner somewhat similar to the change in the overpressure, but the rate of pressure decrease behind the shock front is different. This may be seen from Fig. 3.12 which indicates qualitatively how the two pressures vary in the course of the first second or so following arrival of the shock front.

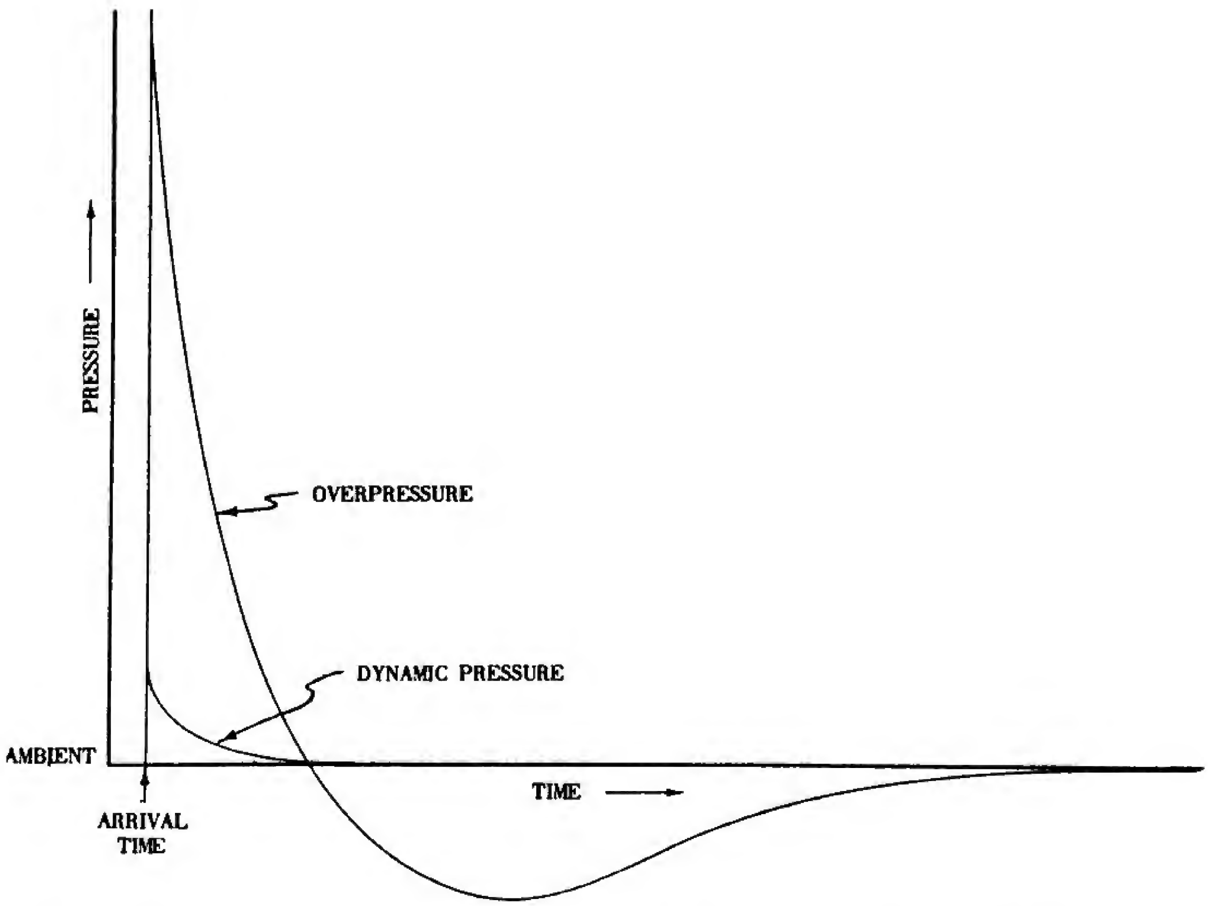


Figure 3.12. Variation of overpressure and dynamic pressure with time at a fixed location.

The curves show the variation of peak overpressure with distance for a 1 KT surface burst and for a 1 KT free-air burst (based on the $2W$ assumption in § 3.94) in a standard sea level atmosphere.

Scaling. For yields other than 1 KT, the range to which a given overpressure extends scales as the cube root of the yield, i. e.,

$$d = d_0 \times W^{1/3},$$

where, for a given overpressure,

d_0 is the distance from the explosion for 1 KT,

and

d is the distance from the explosion for W KT.

Example

Given: A 1 MT surface burst.

Find: The distance to which 2 psi extends.

Solution: From Fig. 3.93 the cube root of 1000 is 10. From Fig. 3.94a, a peak overpressure of 2 psi occurs at a distance of 0.53 mile from a 1 KT surface burst. Therefore, for a 1 MT surface burst,

$$d = d_0 \times W^{1/3} = 0.53 \times 10 = 5.3 \text{ miles.} \quad \textit{Answer}$$

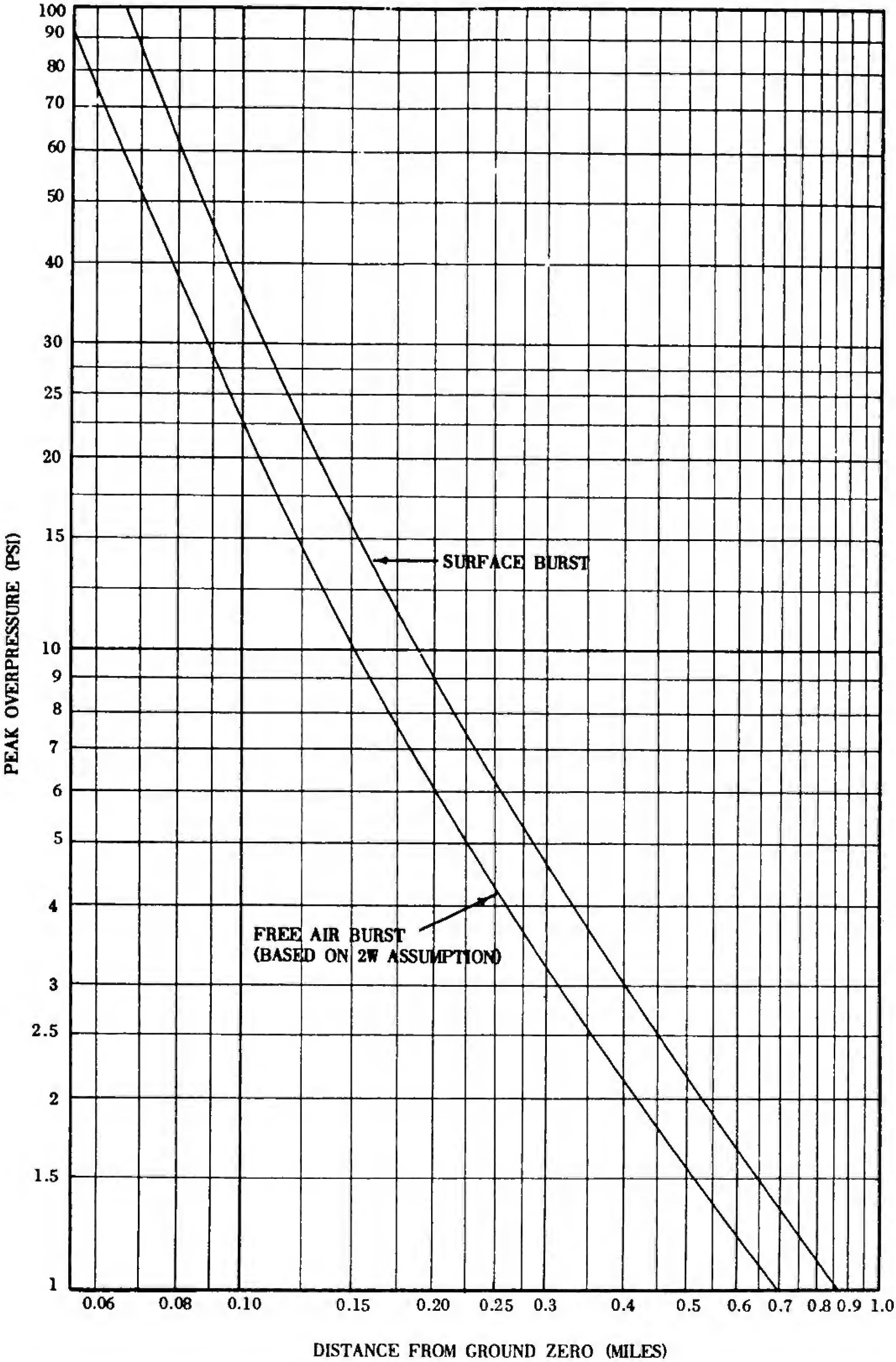


Figure 3.94a. Peak overpressure for a 1-kiloton surface burst and free air burst.

TABLE 6.12

DAMAGE CRITERIA FOR SHALLOW BURIED OR EARTH COVERED SURFACE STRUCTURES

Type of structure	Damage class	Peak over-pressure (psi)	Nature of damage
Light, corrugated steel arch, surface structure (10-gage corrugated steel with a span of 20 to 25 feet) with 3 feet of earth cover over the crown.	A	35–40	Complete collapse.
	B	30–35	Collapse of portion of arch facing blast.
	C	20–25	Deformation of end walls and arch, possible entrance door damage.
	D	10–15	Possible damage to ventilation system and entrance door.
Light, reinforced-concrete surface or underground shelter with 3 feet minimum earth cover. (Panels 2 to 3 inches thick, with beams spaced on 4-foot centers.)	A	30–35	Collapse.
	B	25–30	Partial collapse.
	C	15–25	Deformation, severe cracking and spalling of panels.
	D	10–15	Cracking of panels, possible entrance door damage.

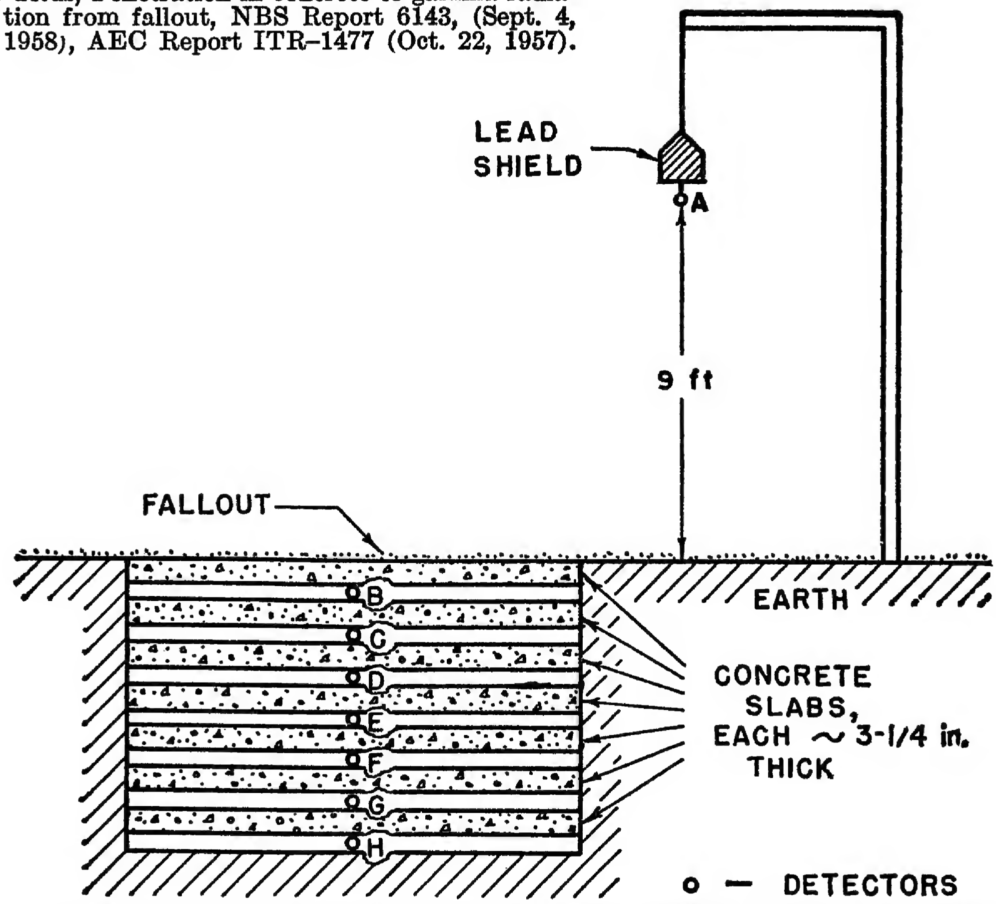
6.13 An illustration of B-type damage to a 10-gage corrugated steel-arch, earth-covered, surface structure is shown in Fig. 6.13. It will be noted that about half of the arch has collapsed. This failure was attributed primarily to the dynamic pressure acting on the forward slope of the earth mound.

6.14 The peak overpressure for the complete collapse of the corrugated steel-arch structure, with 3 feet of earth cover, is given in Table 6.12 as 35 to 40 pounds per square inch. However, it has been estimated that if this structure had been completely buried, so that no earth mound was required, an overpressure of 40 to 50 pounds per square inch would have been necessary to cause it to collapse. This increase in the required overpressure is due to the fact that the dynamic pressure is minimized under these conditions. It may be mentioned

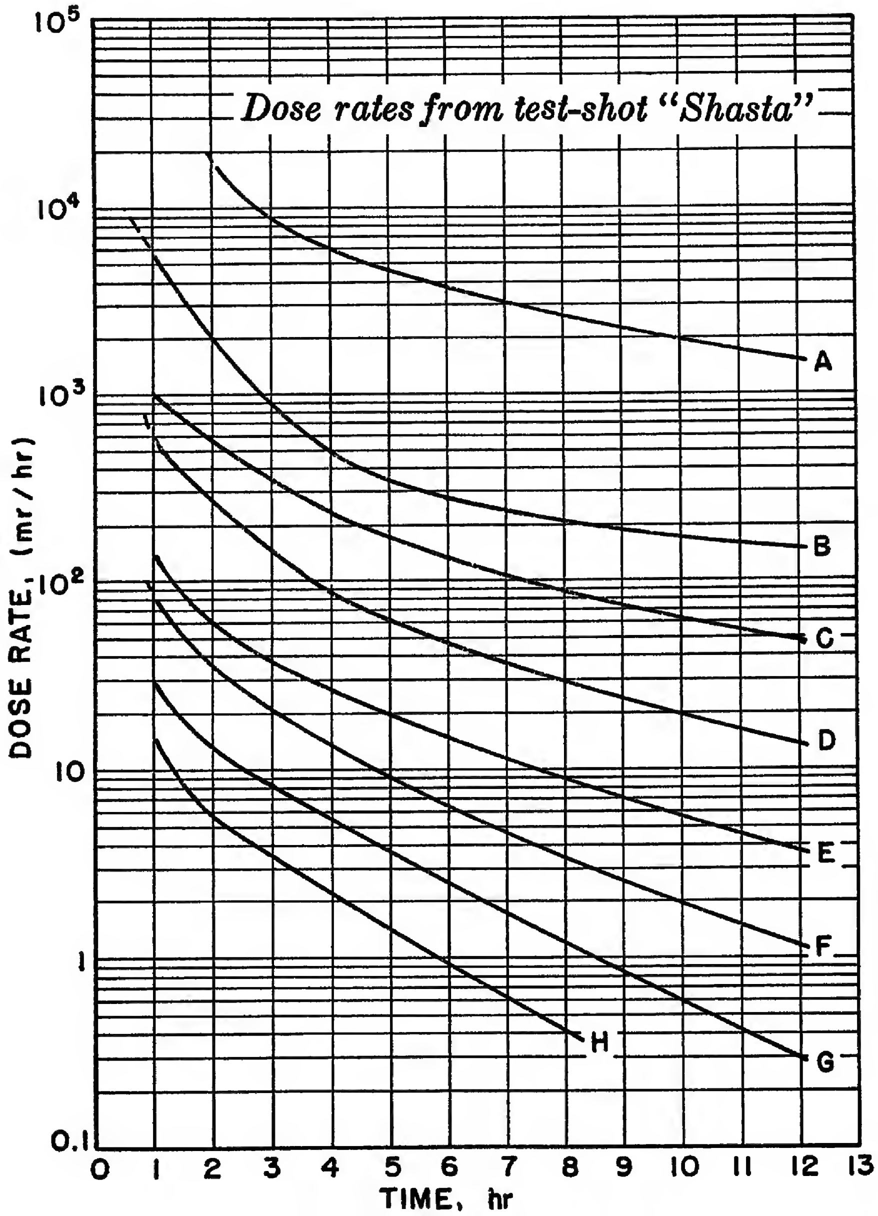
Figure 6.13. B-type damage to earth-covered 10-gage corrugated steel structure.

that, using standard engineering techniques, it is possible to design underground structures which will withstand blast overpressures in excess of 100 pounds per square inch at the surface (see Chapter XII).

F. Titus, Penetration in concrete of gamma radiation from fallout, NBS Report 6143, (Sept. 4, 1958), AEC Report ITR-1477 (Oct. 22, 1957).



The lead shield prevents fallout material from settling directly on detector "A," while at the same time shielding against the intercepted material



A. R. P.

(Air Raid Precautions)

by

J. B. S. HALDANE, F.R.S.

(Co-inventor of 1915 gas masks)

SEPTEMBER
1938

LONDON
VICTOR GOLLANCZ LTD
1938

keyholes and cracks in the wall or between the floor-boards are to be filled with putty or sodden newspaper.

The windows must be specially protected against breakage by blast or splinters.

(Plastic sheets and duct tape for broken windows)

How far are these precautions effective? In 1937 a committee of the Cambridge Scientists' Anti-War Group published a book[1] in which it was stated that no ordinary room is anywhere near gas-proof.

[1] *The Protection of the Public from Aerial Attack.*

Error of Cambridge Scientists' Anti War Group:

The real criticism is as follows. It is unlikely that there would be a lethal concentration of gas out of doors for a long period. The wind carries gas away, and in cities there are vertical air currents even in calm weather. If many tons of bombs could be dropped in the same small area either at once or in succession this would not be so. But given any sort of defence bombs will be dropped more or less at random.

Suppose we had out of doors during 10 minutes a phosgene concentration of one part in 10,000, which would be fatal in a few breaths to people in the street, the concentration inside would never rise as high as $\frac{1}{15}$ of this value[1] if the leakage time were $2\frac{1}{2}$ hours, which is rather low. (Hence protection factor = 15)

[1] Since 10 minutes is $\frac{1}{15}$ of $2\frac{1}{2}$ hours.

Many of the questions which are asked concerning Air Raid Precautions are unanswerable in the form in which they are put. If I am asked "Does any gas mask give complete protection against phosgene" the only literally true answer is "No." One could not live in a room full of pure phosgene in any of them. And one would be killed if a hundred-pound phosgene bomb burst in the room, even when wearing the very best mask. But one would be safe in a phosgene concentration of one part per thousand, of which a single breath would probably kill an unprotected man. Hence in practice such a mask is a very nearly complete protection.

1. Non-persistent gases, such as phosgene. They can be dropped in bombs which burst, and suddenly let loose a cloud of gas, which is poisonous when breathed, but which gradually disperses. If there is a wind the dispersal is very quick; in calm, and especially in foggy weather, it is much slower. These gases can penetrate into houses, but very slowly. So even in a badly-constructed house one is enormously safer than in the open air. Even the cheapest type of gas mask, *provided it fits properly and is put on at once*, gives good protection against them (see Chapter IV).

2. Persistent gases, such as mustard gas. Mustard gas is the vapour of an oily liquid, which I shall call mustard liquid. So far as I know this has not been dropped from aeroplanes in bombs on any great scale. It was used very effectively by the Italians in Abyssinia, who sprayed it in a sort of rain from special sprayers attached to the wings of low-flying aeroplanes.

If the mustard liquid could be sprayed evenly, things would be far more serious. All the outside air of a large town would be poisonous for several days. But this would only be possible if the spraying aeroplanes could fly to and fro over the town in formation, and at a height of not more than 300 feet or so. A fine rain of mustard liquid would probably evaporate on its way to the ground, or blow away, if it were let loose several thousand feet up in the air. Spraying from low-flying aeroplanes was possible in Abyssinia because the Abyssinians had no anti-aircraft guns and no defensive aeroplanes. It would probably not be possible in Britain.

THE HAMBURG DISASTER. Fantastic nonsense has been talked about the possible effects of gas bombs on a town. For example, Lord Halsbury said that a single gas bomb dropped in Piccadilly Circus would kill everyone between the Thames and Regent's Park. Fortunately, although no gas bombs have been dropped in towns in war-time, there are recorded facts[1] which give us an idea of what their effect would be. On Sunday, May 20th, 1928, at about 4.15 p.m., a tank containing 11 tons of phosgene burst in the dock area of Hamburg.

Casualties occurred up to six miles away. In all 300 people were made ill enough to be taken to hospital, and of these ten died. About fifty of the rest were seriously ill. These casualties are remarkably small.

[1] Hegler, *Deutsche Medizinische Wochenschrift*, 1928, p. 1551.

WHY GAS WAS NOT USED IN SPAIN

In view of the terrible stories as to the effects of gas, many people are surprised that it has not been used in Spain. First, why was it not used against the loyalist army? Secondly, why was it not used against towns? The soldiers had respirators after about February 1937, but were not well trained in their use, and often lost them. Very few civilians had any respirators at all.

Gas was not used in the field for several reasons. The main reason is that the number of men and guns per mile was far less than on the fronts in the Great War. Gas is effective if you have a great deal of it,

but the amount needed is enormous. Thus during the night of March 10-11th, 1918, the Germans fired about 150,000 mustard-gas shells into an area of some twenty square miles south-west of Cambrai. If most of the air in a large area is poisoned the effects are serious. But if a few gas shells are fired or a few cylinders let off, the gas soon scatters and ceases to be poisonous, and a man can often run to a gas-free place, even without a mask, before he is poisoned.

Gas was not used against the towns for this reason, and for another, which is very important. Gas only leaks quite slowly into houses, particularly if there are no fires to make a draught, and draw in outside air; and there is very little fuel in loyal Spain.

INCENDIARY BOMBS

These bombs usually contain thermite, which is a mixture of 23 per cent of aluminium powder with 77 per cent of iron oxide (Fe^3O^4).

When such a mixture is heated, the aluminium unites with the oxygen of the iron oxide, and a mixture of alumina slag and white-hot molten iron is produced. This throws out some sparks, but the main effect is downwards. The molten iron penetrates wood, or even thin metal, like so much butter, and sets light to anything inflammable which it touches. Thermite is used in industry for welding.

There are other types of incendiary bomb, for example the phosphorus bomb, which throws burning fragments for some distance, and generates a great deal of smoke. But though it is more alarming, and

more likely to burn people who try to put it out, it has no penetrating power, and the heat is not so great at the centre.

In the early aerial bombardments of Madrid in 1936 a great many incendiary bombs were used. But they were vastly less effective than was expected. The total number of buildings destroyed by them was twenty-three, whereas many hundreds were destroyed by explosive bombs. After the middle of December 1936 no more incendiary bombs were used on Madrid, and they were not used on any great scale against Barcelona, Valencia, or Sagunto, though a few heavy ones weighing 30-50 lbs. were used on Barcelona in the spring of 1938.

PANIC

Panic can be a direct cause of death. If too many people crowd into a shelter, especially one with narrow stairs leading to it, they may easily be crushed to death. In January 1918 fourteen people were killed in this way at Bishopsgate Station in London, and sixty-six were killed in a panic in one of the Paris Underground stations as the result of a false gas alarm.

(Bishopsgate Station incident: 28 January 1918)

BACTERIA AND OTHER MICROBES

It is possible that these will be used in some kind of spray or dust. The difficulty is a technical one. It is easy to disperse many solids as smoke. But this needs heat, and cooked bacteria are harmless. Many

bacteria are killed even by drying. And once bacteria are on the ground they generally stay there. Possibly pneumonic plague or some other air-borne disease might be started by a dust-bomb. Cholera bacilli might be dropped in a reservoir. But they would probably be stopped by filters, and even without this would be likely to die before they reached the houses.

A million fleas weigh very little, and could easily be dropped. In theory they could be infected with plague. In practice this would need a staff of hundreds of trained bacteriologists, and huge laboratories. So with other possible means of infection. Some may very well be tried, if only to create a panic, but I would sooner face bacteria than bombs.

Certain pacifist writers are severely to blame for our present terror of air raids. They have given quite exaggerated accounts of what is likely to happen.

So long as civilian populations are unprotected, criminal States will continue to murder the citizens of their weaker neighbours and to blackmail the stronger.

PHYSICAL PROPERTIES OF A GAS-CLOUD. Every student of chemistry learns that a heavy gas such as chlorine can be poured from one vessel into another almost like water, whilst a light gas such as hydrogen rapidly rises. Now all the poisonous gases and vapours used in war are heavier than air, so it is thought that they would inevitably flood cellars and underground shelters, and that on the first floor of a house one would not be safe.

But within a short time it would be mixed with many times its volume of air. Now air containing one part in 10,000 of phosgene is extremely poisonous. But its density exceeds that of air by only one part in 4,000.

GAS-MASKS, AND GAS-PROOF BAGS FOR BABIES

THE EARLIEST GAS-MASKS made in 1915, relied on chemical means to stop chlorine, which was the first gas used. A cloth soaked with sodium phenate or various other compounds will stop chlorine on its way through. But it would not stop carbon monoxide, mustard gas, or many other gases. The terrible prospect arose that it would be necessary to devise a new chemical to stop each new gas. There would be a continual series of surprise attacks with different gases, each successful until a remedy was found, and each involving the death of thousands of men.

It is a most fortunate fact that the majority of vapours can be removed from air, not by chemical combination, but by a process called adsorption, which is non-specific. For example lime will stop an acid gas such as carbon dioxide, and woollen cloth soaked in acid will stop an alkaline gas such as ammonia. No single chemical will combine with both.

But charcoal, silica, and various other substances, when properly prepared, will take up vapours of different chemical types. The molecules form a very thin liquid layer on the surface of the adsorbent, as indeed they do on glass or metals. But charcoal is full of pores and has an enormous surface per unit of weight; so it can take up a great deal of gas.

The main characteristic in a vapour which renders it adsorbable is that it should be the vapour of a liquid with a high boiling point. Thus carbon monoxide boils at–190° C, and is hardly adsorbed at all. Phosgene boils at 8° C and is fairly easily adsorbed. Mustard gas boils at 217° C and is very easily adsorbed indeed. This has a lucky consequence. It is quite sure that there are no unknown poisonous gases with a boiling point as low as that of carbon monoxide. For only a substance with very small molecules can have so low a boiling point. And chemists have made all the possible types of very small molecules. It is unlikely that there are any unknown poisonous gases with as low a boiling point as phosgene, though it is just possible. But if there are they will probably be stopped by charcoal. There may very possibly be some vapours of high boiling point more poisonous than mustard gas. But if so I am prepared to bet a thousand to one that charcoal will stop them all.

THE PROTECTION OF THE PUBLIC FROM AERIAL ATTACK

Being

A CRITICAL EXAMINATION OF THE RECOMMENDATIONS PUT FORWARD BY THE AIR RAID PRECAUTIONS DEPARTMENT OF THE HOME OFFICE

by

THE CAMBRIDGE SCIENTISTS' ANTI-WAR GROUP

First published February 12th 1937
Second impression February 12th 1937

LONDON

VICTOR GOLLANCZ LTD

1937

the time taken for the gas to leak out to half its original value was measured in four rooms—the basement of a shop, the dining-room of a semi-detached house, the sitting-room of a Council house and the bathroom of a modern villa. As stated above the leakage half-times for these rooms were $2\frac{1}{2}$, $2\frac{1}{2}$, $3\frac{1}{2}$ and $9\frac{1}{4}$ hours respectively. The reason for the last room being so much better than all the others is that it has steel-frame windows which were sealed with plasticine, painted and tiled walls, and a concrete floor covered with cork tiles.

Note: even a 1 mile wide gas cloud passes in 6 min in 10 miles/hr wind (hence good protection) 41 This property of drifting with the wind is of some importance, for it means that the gas will not remain for long periods in any one place except on still days.

Now it may be objected that, although the "gas-proof" room is not hermetically sealed, it will nevertheless protect the occupants for the two or three hours necessary in case of an attack by a choking gas.

E. Madgwick, *Philosophical Magazine*, 12.1160.1931: "Taking 15 cm. of water as wind pressure, the rate of flow through 9 inch (brick) wall covered with 1 inch plaster sized, papered and distempered is ·0084 cubic metres per square metre per hour."

We assume that the gas blows away so quickly that every 10 minutes its concentration is halved. In Engelhard's experiments it took 10 minutes to liberate the gas from its cylinders, so that this assumption is reasonable. Then a person occupying a good "gas-proof" room, the leakage half-time of which (defined on p. 18) is 3 hours, would have breathed a lethal dose of phosgene in 2 hours.

Gas-schutz und Luftschutz, *4*, 174, 1934

Complete lies: bombs are dropped, not cylinders. Engelhard's 1934 article in the Nazi controlled "Gas protection and air protection" journal is enemy propaganda; the Nazis kept the facts secret.

As, however, our experiments on the "gas-proof" room illustrate quite clearly that the ordinary dwelling-house is quite incapable of affording protection, it probably will not matter much what a civil population does under a gas and incendiary attack. Nor is it profitable to argue whether the gas or incendiary bomb is the more devastating, as it is necessary to contemplate an air attack in which both will be employed, with a sprinkling of high explosive bombs, which will considerably heighten the "psychological effect." This is the type of attack which people in large towns must expect if war breaks out; our task in this section is to discuss the proposals of the Home Office for dealing with incendiary bombs, remembering that whoever deals with them will require, almost certainly, simultaneous protection against gas. PROVED WRONG!

PROPAGANDA

extreme lightness and cheapness of the incendiary bomb must be borne in mind. Mr. Noel-Baker cites the case of a single aeroplane carrying a load of less than a ton of bombs which succeeded in starting three hundred fires, and if we take a specimen raid of nine bombers, each carrying a thousand "kilo" bombs, nine thousand of these could be dropped on an area of two square miles. If very generous allowances are made for failures to function and for bombs falling on non-inflammable sites, in an urban area one fifth at least of these bombs should cause fires. This makes one thousand eight hundred fires. The danger of fire spreading over several blocks of buildings as in the San Francisco (1906) and Tokyo (1933) earthquakes, making the centre of the conflagration quite unapproachable by fire brigades is obvious.

To summarise this section, we reach the conclusion:

(*a*) That for individuals the cost of making buildings impenetrable to incendiary bombs is prohibitive.

(*b*) That, bearing in mind the probability of combined incendiary and gas attack, the civilian population will have considerable difficulty in extinguishing fires caused by incendiary bombs in private houses, unless assisted by experts. ← WRONG!

(*c*) That the fires caused by a raid such as is outlined above would very likely be impossible to deal with, even with the improved fire brigade organisation envisaged by the Home Office, because of the probable amalgamation of separate outbreaks into a vast conflagration.

ornl

OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

ORNL/TM-10423

Technical Options for Protecting Civilians from Toxic Vapors and Gases

C. V. Chester

Date Published - May 1988

Prepared for
Office of Program Manager
for
CHEMICAL MUNITIONS
Aberdeen Proving Grounds, Maryland

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Table 1. Chemical Agent Toxic Properties[1]

Agent	Volatility (mg/m^3, 25^oC)	Median Lethal Concentration X Time (mg/m^3 *min)		Median Incapacitation Concentration X Time (mg/m^3 *min)
		Respiratory	Percutaneous	
Chlorine (CL)	2.2×10^7	19,000	-	1,800
Phosgene (CG)	4×10^6	3,200	-	1,600
Hydrogen Cyanide (AC)	1×10^6	2,000-4,500	-	>2,000
Cyanogen Chloride (CK)	1×10^6	11,000	-	7,000
Sulfur Mustard (HD)[2]	920	1,500	10,000	200
Nitrogen Mustard (HN-1)	2,000	1,500	20,000	200
Lewisite (L)[2]	6,000	1,200-1,500	100,000	300
Mustard Lewisite (HL)	4,200	1,500	>10,000	200
Tabun (GA)[2]	610	400	40,000	300
Sarin (GB)[2]	22,000	100	15,000	35-75
Soman (GD)	3,900	100	1,000	35-75
VX[2]	10.5	100	1,000	50
Methyl Isocyanate		1500		

[1]Taken from U.S. Department of the Army (1975) and WHO (1970).

[2] Chemical agents in the stockpile to be destroyed in this program.

DISTANCE AND ATMOSPHERIC DISPERSION

As a toxic cloud moves downwind it mixes with ever increasing amounts of air, becoming larger and more dilute. Diffusion of the vapor vertically and at right angles to direction of motion reduces the exposure to someone standing in the path of the cloud. Diffusion forward and backwards along the direction of travel in general does not reduce the amount inhaled by someone in the path of the cloud.

The rate of vertical and lateral mixing of the toxic cloud with the surrounding air can vary enormously depending on weather conditions. A bright, sunshiny day promoting convection of the atmosphere close to the ground will cause rapid vertical mixing. A turbulent wind will promote lateral mixing. High windspeeds also reduce the time that a person is immersed in a passing cloud and directly reduces the amount they will inhale for given quantity going by. The worst conditions providing the greatest threat to people at the greatest distance downwind occur under conditions of light, steady winds, a clear night with cooling of the ground to cause vertical stability in the atmosphere and the existence of a temperature inversion not too far above the ground to trap the chemical close to the ground. Conditions very close to these were responsible for the large casualties at the Bhopal incident in India.

Figure 1 shows the downwind hazard from clouds of 1000 kilograms of each of several toxic gases moving at 1 meter per second (approx. 2 miles per hour) in a highly stable atmosphere (Pasquill type E). These conditions also assume an inversion at 750 meters. Calculations use the Army's D2PC code (Whitacre et al, 1986). The dependent variable in Fig. 1 is given as the protection factor offered by protective measures required to prevent 99 percent of the fatalities at each location downwind. For example for GB, to keep the dose down to 1 percent fatalities at 1 kilometer downwind, the population would have to have masks or other protection giving a protection factor of a little less than 700. The

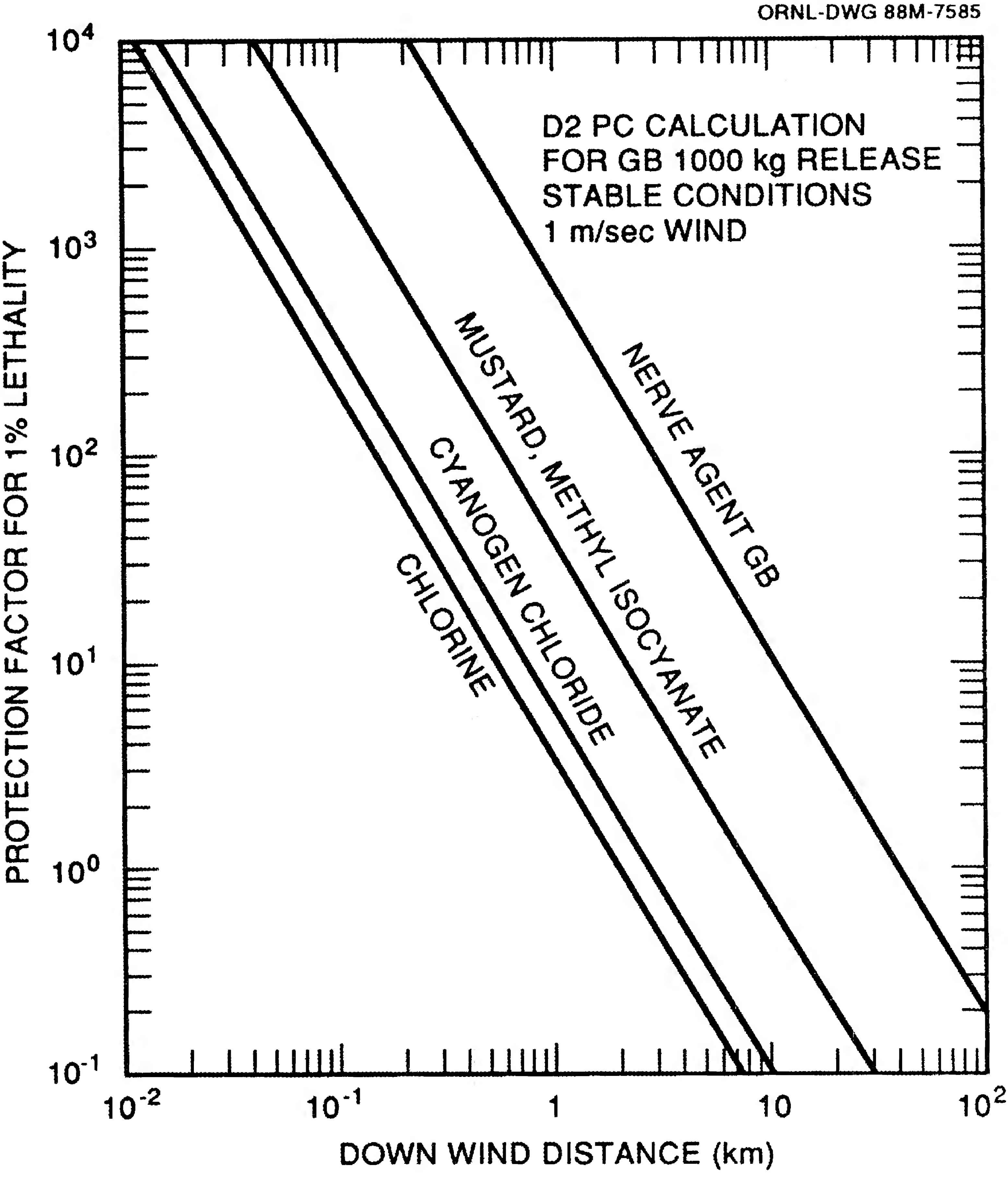


Fig. 1 Dose vs Downwind Distance for Some Very Toxic Gases

protection factor is the ratio of the dose people would get with no mask compared to what they would get if they were wearing a gas mask.

As can be seen from Fig. 1 the requirement for gas masks diminishes rapidly as one gets further away from the point of release of a quantity of agent. Under sunny conditions with a higher wind speed the requirement for protection would decrease even more rapidly. For the purposes of this study, these relatively pessimistic meteorological conditions (1.0 m/s. wind velocity, type E stability, inversion at 750 m) will be assumed in all cases.

EVACUATION

Evacuation is a way of increasing the distance between the population and a hazard and is the countermeasure to toxic chemical releases with which there is the most experience. Sorensen and his colleagues have reviewed the subject thoroughly (1987). It is very effective for slowly (few hours) developing hazards and in areas where emergency plans employing evacuation have been developed. Slowly developing chemical hazards can include a relatively small leak of a volatile toxic chemical, a large spill of a low volatility but highly toxic substance, or a progressive accident (e.g. fire) which doesn't at first cause release of toxic chemicals but has the potential of spreading to nearby equipment, tanks or drums containing toxics. Where small areas are threatened, evacuation can be quite effective.

Situations where taking shelter may be preferable to evacuating include quick release of small quantities of volatile toxic chemicals, or circumstances where an evacuation is likely to result in a traffic jam. This latter is a possibility where the area at risk is large, the population density is high, and the time available is short.

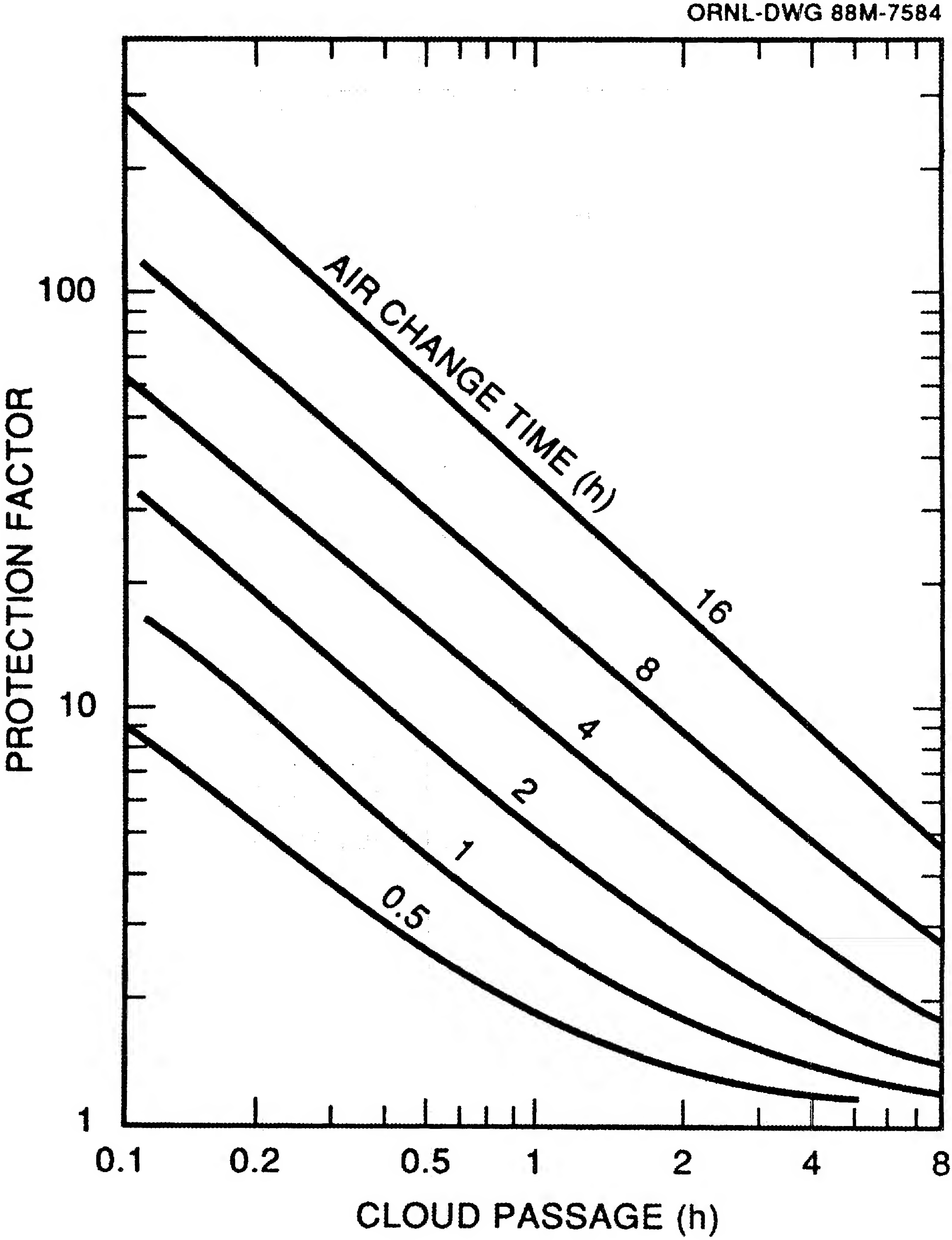


Fig. 2 Protection Factor of Leaky Enclosures

ORNL-DWG 88M-7581

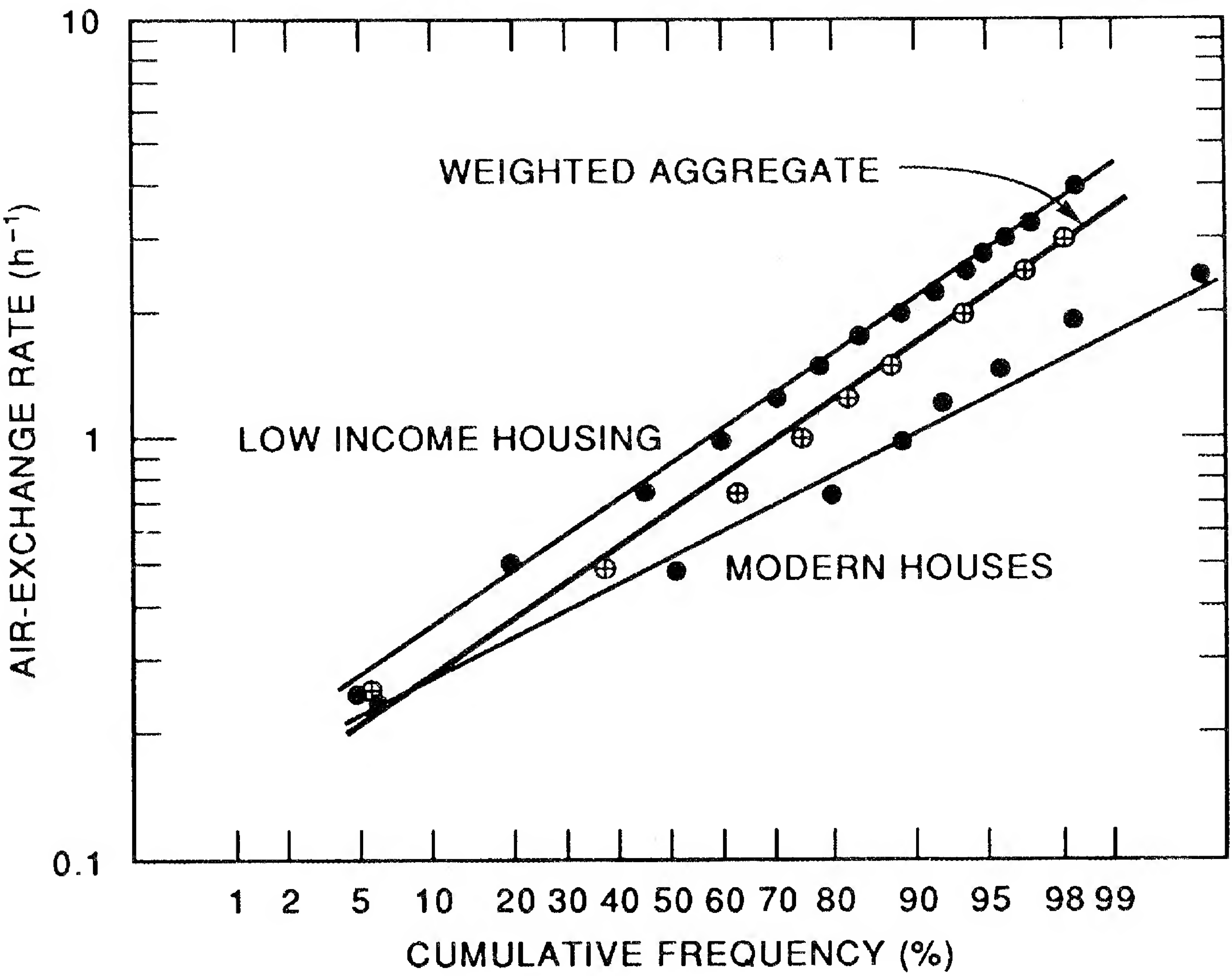


Fig. 3 Infiltration Rates of American Residences

Sorensen, J.H., 1988, Evaluation of Warning and Protective Action Implementation Times for Chemical Weapons Accidents, ORNL-TM/10437, Oak Ridge National Laboratory, Oak Ridge, TN 37831.

U.S. Department of the Army 1975, Military Chemistry and Chemical Compounds, FM3-9/AFR 355-7.

Whitacre, G.C. et al, Personal Computer Program for Chemical Hazard Prediction (D2PC), U.S. Army Chemical Research and Development Center, Aberdeen Proving Ground, MD.

Wilson, D. J. 1987, Stay Indoors or Evacuate to Avoid Exposure to Toxic Gas, Emergency Preparedness Digest (Canada) 14 no. 1.

World Health Organization, 1970, Health Aspects of Chemical and Biological Weapons, Geneva, Switzerland.

ORNL/TM-2001/154

Energy Division

Will Duct Tape and Plastic Really Work? Issues Related To Expedient Shelter-In-Place

John H. Sorensen
Barbara M. Vogt

Date Published—August 2001

Prepared for the
Federal Emergency Management Agency
Chemical Stockpile Emergency Preparedness Program

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

Expedient sheltering involves the use of common materials to enhance the safety of a room inside a building against the impacts of a chemical plume. The central premise behind taping and sealing with duct tape and plastic is to reduce airflow into a room. Vapors penetrate into a room through cracks and openings in the walls, floors and ceilings, around doors and windows, and through openings for ducts, light fixtures, fans, pipes, electrical outlets, chimneys, door handles, and locks. The goal of taping and sealing is to significantly reduce infiltration at these points.

Expedient sheltering was suggested by NATO (1983) using the term “ad-hoc shelter” to protect civilian populations from chemical warfare agent exposure. The concept was to use plastic sheeting to seal off a room by fashioning a simple airlock at the entrance to the room and sealing off doors, windows or louvered vents. The NATO guidelines also stressed the need for rapid exit from the ad-hoc shelter once the plume had passed to avoid further exposure (NATO 1983, p. 143).

This strategy was further developed by the Israeli Civil Defense in the mid-1980s to protect the public against a chemical weapons attack (Yeshua 1990). The tape and seal strategy was in place when the Gulf War occurred in 1991 and received considerable media attention. The Israeli strategy was to have citizens prepare a “safe room” in their house or apartment with the use of weatherization techniques to permanently reduce infiltration. Citizens were also instructed to take expedient measures, such as sealing

doors and windows with plastic sheets, in the event of a chemical weapons attack. The use of plastic over a window was developed to reduce air infiltration and to provide a vapor barrier in the event of glass breakage from bomb explosions. A modification of the Israeli strategy was proposed for use in CSEPP (Sorensen 1988; Rogers et al. 1990).

Although vapors, aerosols, and liquids cannot permeate glass windows or door panes, the amount of possible air filtration through the seals of the panes into frames could be significant, especially if frames are wood or other substance subject to expansion and contraction. To adequately seal the frames with tape could be difficult or impractical. For this reason, it has been suggested that pieces of heavy plastic sheeting larger than the window be used to cover the entire window, including the inside framing, and sealed in place with duct or other appropriate adhesive tape applied to the surrounding wall.

Another possible strategy would be to use shrink-wrap plastic often used in weatherization efforts in older houses. Shrink-wrap commonly comes in a 6 mil (0.006-in.) thickness and is adhered around the frame with double-faced tape and then heated with a hair dryer to achieve a tight fit. This would likely be more expensive than plastic sheeting and would require greater time and effort to install. Because double-faced tape has not been challenged with chemical warfare agents, another option is to use duct tape to adhere shrink-wrap to the walls. Currently, we do not recommend using shrink-wrap plastics because of the lack of information on its suitability and performance.

3. WHY WERE THESE MATERIALS CHOSEN?

Duct tape and plastic sheeting (polyethylene) were chosen because of their ability to effectively reduce infiltration and for their resistance to permeation from chemical warfare agents.

3.1 DUCT TAPE PERMEABILITY

Work on the effectiveness of expedient protection against chemical warfare agent simulants was conducted as part of a study on chemical protective clothing materials (Pal et al. 1993). Materials included a variety of chemical resistant fabrics and duct tape of 10 mil (0.01-in.) thickness. The materials were subject to liquid challenges by the simulants DIMP (a GB simulant), DMMP (a VX simulant), MAL (an organoposphorous pesticide), and DBS (a mustard simulant). The authors note that simulants should behave similarly to live agents in permeating the materials; they also note that this should be confirmed with the unitary agents. The study concluded that "duct tape exhibits reasonable resistance to permeation by the 4 simulants, although its resistance to DIMP (210 min) and DMMP (210 min) is not as good as its resistance to MAL (>24 h) and DBS (> 7 h). Due to its wide availability, duct tape appears to be a useful expedient material to provide at least a temporary seal against permeation by the agents" (Pal et al. 1993, p. 140).

3.2 PLASTIC SHEETING PERMEABILITY

Tests of the permeability of plastic sheeting (polyethylene) challenged with live chemical warfare agents were conducted at the Chemical Defense Establishment in Porton Down, England in 1970 (NATO 1983, p. 133). Agents tested included H and VX, but not GB. Four types of polyethylene of varying thickness were tested: 2.5, 4, 10 and 20 mil (0.0025, 0.004 in., 0.01 in., and 0.02 in.). The results of these tests are shown in Table 1.

Table 1: Permeability of plastic sheeting to liquid agent

	Breakthrough time (h)	
Thickness	VX	H
0.0025	3	0.3
0.004	7	0.4
0.01	30	2
0.02	48	7

Source: NATO 1983, p. 136.

The data shows that at thickness of 10 mil or greater, the plastic sheeting provided a good barrier for withstanding liquid agent challenges, offering better protection against VX than for H. Because the greatest challenge is from a liquid agent, the time to permeate the sheeting will be longer for aerosols and still longer for vapors, but the exact relationship is unknown due to a lack of test data.

In Fig. 1 we plot the data in Table 1 to determine the nature of the relationship between thickness and breakthrough time. The data suggest a somewhat linear relationship, thus allowing some interpolation for various thickness of plastic sheeting. For reference, commercially available sheeting is typically sold at 0.7, 1, 1.2, 1.5, 2, .2.5, 3, 4, 6, and 10 mil. although thicker material is available (up to 100 mil). Plastic painter drop cloths are sold between 0.5 and 2 mil.

4. HOW HAVE THEY PERFORMED IN TESTS OR REAL EVENTS?

Although the “safe room” strategy was used in the many scud missile attacks against Israel in the Gulf War, no chemical agents were released during these attacks. Sheltering has been recommended as a protective action in several chemical releases in the United States and Canada. Some anecdotal information exists about sheltering effectiveness in those events, but no empirical studies of actual effectiveness in a real event have been conducted. Such data would be extremely difficult to capture. Two sets of experiments have been conducted on the effectiveness of in-place sheltering (Rogers et al. 1990; Blewett et al. 1996).

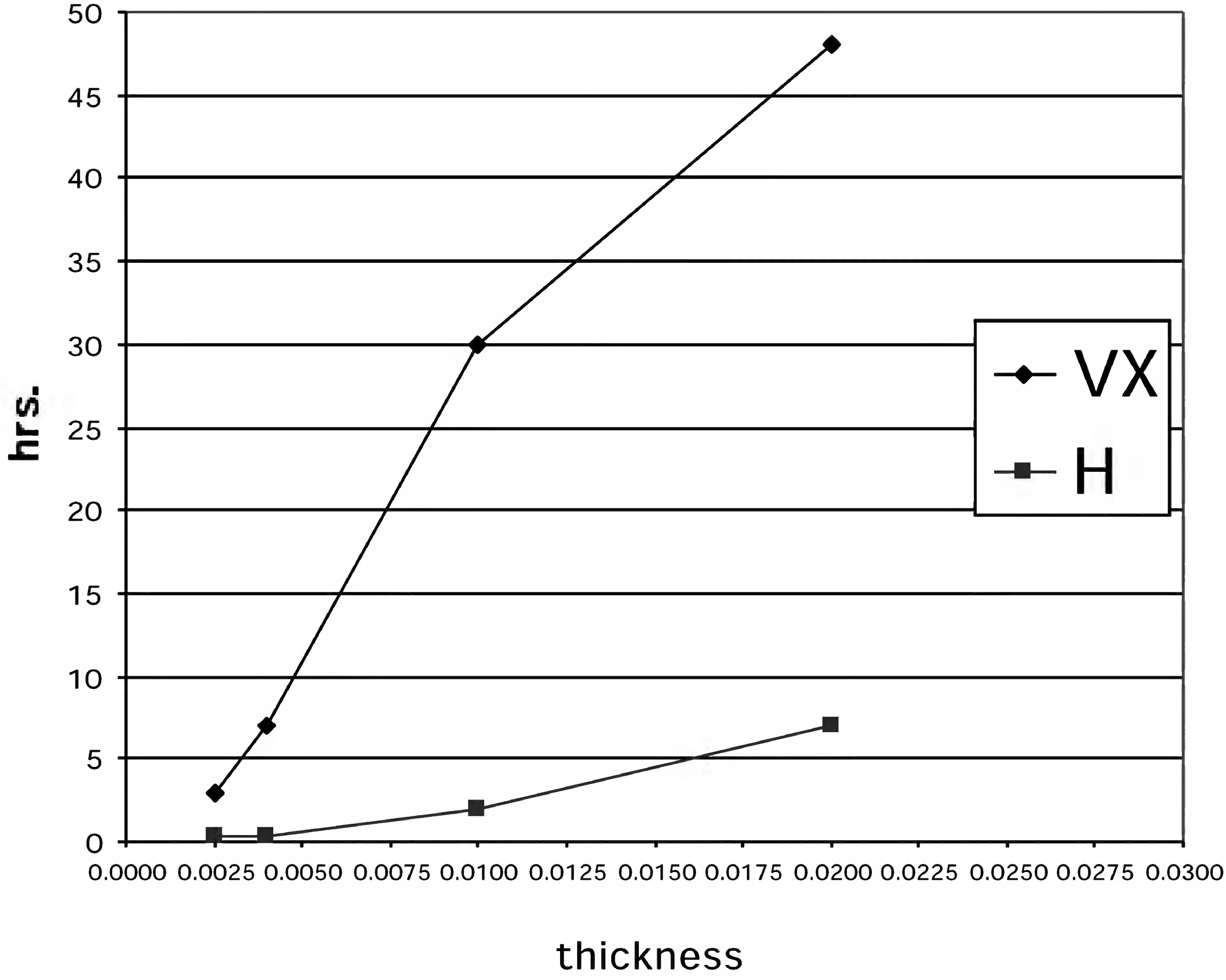


Fig. 1. Breakthrough as a function of the thickness of plastic sheeting.

The results of the two sets of experiments or trials using tracer gas methods provide some insight into the effectiveness of expedient sheltering. These trials were conducted in the vicinity of Oak Ridge, TN., in the late 1980s and Edgewood, MD in the mid 1990's. The Oak Ridge tests involved 12 single-family homes. The trials measured the air exchange for the whole house, the expedient room (mainly bathrooms) with a towel against the door, and the bathroom fully taped and sealed by a household member. Materials used included duct tape, flexible insulation cord, and plastic sheeting. In each test, subjects were given written instructions and checklists, but were left to make the decision how to seal the room.

Infiltration or air exchange is measured by the number of air changes per hour (ach). The average air exchange rate for the houses tested in the Oak Ridge trials was 0.45 ach. The bathrooms with a towel averaged only 0.94 ach. The fully sealed bathrooms averaged

0.33 ach, a reduction of 0.61 ach or 65% (0.61/0.94). One factor not assessed in the study was the air exchanged between the sealed room and the whole house versus the sealed room and the outside. If one assumes that the air exchanged by the room is mostly with the rest of the house, an added protection factor would be achieved because the contaminated air concentrations outside the house are reduced by mixing with air in the whole house and then reduced again in the expedient room. If it is assumed that most of the exchange is between the room and the outside, little added protection beyond that provided by the room would be achieved.

The tests in Edgewood, Maryland, involved 10 residential buildings and 2 mobile homes. Three types of rooms were tested: bathrooms with windows, windowless bathrooms, and walk-in closets. The expedient measures were applied by technicians, and the doors were taped from the outside of the room. A total of 36 trials were performed using different configurations of protection. The results (Table 2) show the air exchange rate for the whole house and for the room in which the expedient measure(s) was applied. The most aggressive strategy (Method 2) proved to be fairly effective, reducing average air exchange rates to between 0.15 and 0.21 ach.

Table 2: Results of Edgewood trials

Room and method	Average house ach	Average room ach
Bathroom—no expedient measures	0.29	0.27
Method 1: Bathroom—wet towel and taped vent	0.28	0.23
Method 2: Bathroom—door taped, plastic sheet on window, wet towel and taped vent	0.32	0.21
Windowless bathroom—no expedient measures	0.37	0.29
Method 1: Windowless bathroom—wet towel and taped vent	0.33	0.29
Method 2: Windowless bathroom—door taped, wet towel and taped vent	0.34	0.15
Walk in closet—no expedient measures	0.39	0.28
Method 1: Walk in closet—wet towel and taped vent	0.44	0.30
Method 2: Walk in closet—door taped, wet towel and taped vent	0.21	0.15

A good way of examining the numbers in the table is to compare the baseline case (door closed with no expedient protection) to the case with the greatest amount of expedient protection (Method 2). For the bathroom, the ach dropped from 0.27 to 0.21 (22%). For the windowless bathroom, the ach dropped from 0.29 to 0.15 (48%). For the closet, the ach dropped from 0.28 to 0.15 (46%).

The results of the two studies are consistent. Both studies showed a reduction of average air exchange rates from expedient protective measures. In some of the specific rooms tested such measures substantially reduced air infiltration into the sealed room when compared to the unsealed room. Infiltration was reduced in one trial by 90% in the

Oak Ridge study and by 57% in Edgewood study. In addition, fairly low air exchanges were achieved in some of the specific expedient room trials (0.11 ach in both studies). The effectiveness of individual trials varied. In the Oak Ridge study, the lowest reduction was 13% and highest air exchange rate was 0.58 ach. In the Edgewood study, the highest air exchange rate for the most aggressive strategy (Method 2) was 0.31 ach. The greater variability in the Oak Ridge data likely results from the variability in the way individuals implemented the taping and sealing, which was more uniform in the Edgewood study because taping was done in a consistent manner by a skilled technician.

5. TIMING OF EXPEDIENT SHELTER

In the ORNL study (Rogers et al. 1990), the time to implement the expedient protection was recorded. Overall times ranged between 3 and 44 min in total, with a mean of 19.8 min. The time to close up the house was relatively short, with a mean of 3.2 min with a range of 1 to 6 min. Times to tape and seal ranged between 2.3 and 38.6 min, with a mean of 16.7 min. These data are shown in Fig. 2.

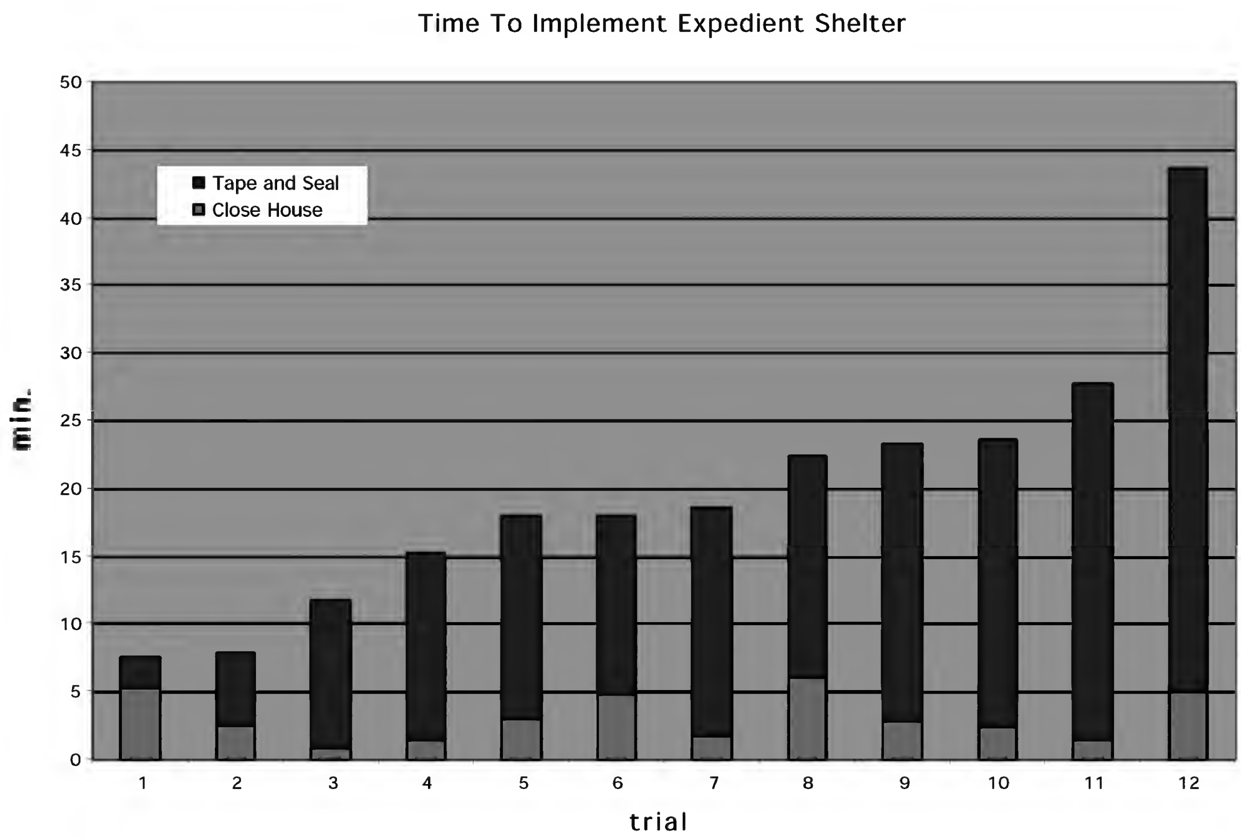


Fig. 2: Expedient shelter trial times.

8. REFERENCES

Blewett, W. K., D. W. Reeves, V. J. Arca, D. P. Fatkin, and B. D. Cannon 1996. *Expedient Sheltering in Place: An Evaluation for the Chemical Stockpile Emergency Preparedness Program*, ERDEC-TR-336, Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, Md.

NATO Civil Defense Committee 1983. *NATO Handbook on Standards and Rules for the Protection of the Civil Population Against Chemical Toxic Agents*, AC/23-D/680, 2nd rev.

Pal, T., G.Griffin, G. Miller, A. Watson, M. Doherty, and T. Vo-Dinh. 1993. "Permeation Measurements of Chemical Agent Simulants Through Protective Clothing Materials," *J. Haz. Mat.* **33**:123-141.

Rogers, G. O., A. P. Watson, J. H. Sorensen, R. D. Sharp, and S. A. Carnes. 1990. *Evaluating Protective Actions for Chemical Agent Emergencies*, ORNL-6615, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Sorensen, J. H. 1988. *Evaluation of Warning and Protective Actions Implementation Times for Chemical Weapons Accidents*, ORNL/TM-10437, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Yeshua, I. 1990. *Chemical Warfare: A Family Defense Manual*, Centre for Educational Technology, Ramat Aviv, Israel.

U.S. Department of the Army and Federal Emergency Management Agency. 1996. Planning Guidance for the Chemical Stockpile Emergency Preparedness Program, Washington, D.C.

FINAL REPORT

11 March 1963

Recovery and Decontamination Measures after Biological and Chemical Attack

This report has been reviewed in the Office of Civil Defense and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Office of Civil Defense.

Contract OCD-OS-62-183

Prepared for
Office of Civil Defense
Department of Defense

by

Science Communication, Inc.
1079 Wisconsin Avenue, N.W.
Washington 7, D. C.

To plan for countermeasures against any weapons one must understand the problem—the nature, the potentials, and the limitations. This research project and the resultant final report were intended to bring together current information most applicable to civil defense. It was particularly intended for those who are responsible for planning preparatory, reclamation and countermeasures effort to minimize the damage from a BW/CW attack.

William J. Lacy
Project Coordinator
Postattack Research

Decontaminants

An important class of decontaminants comprises the common substances or natural influences such as time, air, earth, water, and fire.

Natural Effects

Biological agents are living organisms and tend to die off with time unless they are in a favorable environment with moisture, food, warmth, and other factors necessary for their survival. In addition, most biological organisms are very sensitive to the conditions of temperature and humidity -- and, particularly to the ultra-violet portion of sunlight. Adverse exposure to the elements -- air, sunlight, high temperature, low humidity -- is effective, in fact, against all biological agents except the spore forms of bacterial organisms.

It is generally assumed that in the vegetative form bacteria (as contrasted to the spore form) can persist for less than two hours during daytime and about eighteen hours at night. Since these short-lived bacteria are the most probable agents, outdoor decontamination is usually not called for unless the agent has been identified, either by laboratory tests or by the character of the disease, as one which forms spores or is otherwise known to be persistent.

The persistent, low-volatile, agents such as the liquid nerve agents (V-agents) and the blister gases present the principal chemical decontamination problem. Even these evaporate in time. The speed of evaporation and dissipation is enhanced by higher temperatures and wind. Thus, if it is possible to avoid the area or the use of contaminated objects for a reasonable length of time, decontamination may be unnecessary. Such periods might run from hours to a few days, depending on the degree of contamination and weather conditions. In cold weather the agents will persist for longer periods.

Water

Next to weathering, the most important natural decontaminant is water, used either to remove the agent, with or without soap or detergents to assist, or by boiling. One caution -- water used to wash away contamination becomes contaminated and must be disposed of accordingly. Boiling destroys most chemical agents and all biological agents. When it is feasible, boiling is one of the most generally desirable methods -- particularly for household use by individuals.

Earth and fire, the other natural decontaminants, would have relatively little application in civil defense BW/CW decontamination operations. Earth may be used to cover contamination temporarily to keep it out of contact with people while natural processes either dissipate or destroy the agent. This involves substantial effort with bulldozers and earth-moving equipment and usually is neither practical or necessary.

Chemical Decontaminants

These are preferred when they are available. Chemical decontaminants fall in two classes -- those which destroy or neutralize the agents, and those which simply assist in their removal.

The principal decontaminants which destroy or neutralize are:

- Chlorine-containing materials, such as calcium hypochlorite (HTH) and sodium hypochlorite solutions. Many household disinfectants available under various brand names -- Clorox, Purex, etc. -- are sodium hypochlorite solutions.

- Alkalies, such as caustic soda (lye) and sodium carbonate (washing soda, or soda ash).

The chlorine-containing materials, in proper concentrations, are effective against both biological and chemical agents. As solutions they are used to decontaminate surfaces, as in washing off sealed food containers; for decontaminating cotton fabrics by soaking or addition during the washing process; and for sterilizing water. Hypochlorite solutions have the disadvantage of corroding metals and so must be rinsed off thoroughly.

The hypochlorites -- calcium and sodium -- are the preferred decontaminants for blister gases and liquid nerve agents. For most such applications they are used as solutions but for vertical surfaces or porous surfaces a "whitewash" of calcium hypochlorite (HTH), hydrated lime, and water (called a "slurry") is more effective

Appraisal of Biological and Chemical Warfare Protection in the U.S. Field Army. Booz, Allen Applied Research, Inc., June 1961. AD 329 113, (SECRET).

Area-Coverage Capabilities of Bacteriological and Chemical Weapons (U). Tamplin, A.R., Rand Corporation, April 1962. AD 329 207, (SECRET).

Biological Decontamination. Asher, T.M., Naval Biological Laboratory, February 1954. AD 72 485, (SECRET).

Biological Problems Attendant Upon the Application of Bacteriological and Chemical Agents in Limited War (U). Tamplin, A.R., Rand Corporation, RM-2677, June 1961. AD 324 462, (SECRET).

Chemical and Biological Weapons Employment. Department of the Army Field Manual, FM 3-10, February 1962.

Community Reaction to an Accidental Chlorine Exposure - Task Sirocco. Segaloff, Louis, University of Pennsylvania, November 1961. AD 269 681.

Decontamination of Water Contaminated with VX. Lindsten, Don C. and Bauer, Virginia E., U.S. Army Engineer Research and Development Laboratories, Research Report 1630-RR, May 1960. AD 239 310.

Effects of Cooking and Baking Processes on the Sterilization of Food Contaminated with Bacterial Spores. Commissary Research Division, U.S. Naval Supply Research and Development Facility, Final Report Navy Project NT 002 024 (CR 53-89), 1953.

Evaluation of Standard and Modified Laundering Procedures as BW Decontamination Methods. Portner, Dorothy M., Mayo, Elizabeth C. and Surkiewicz, Bernard F., Biological Warfare Laboratories, Technical Memorandum 1-2, March 1959. AD 252 270L.

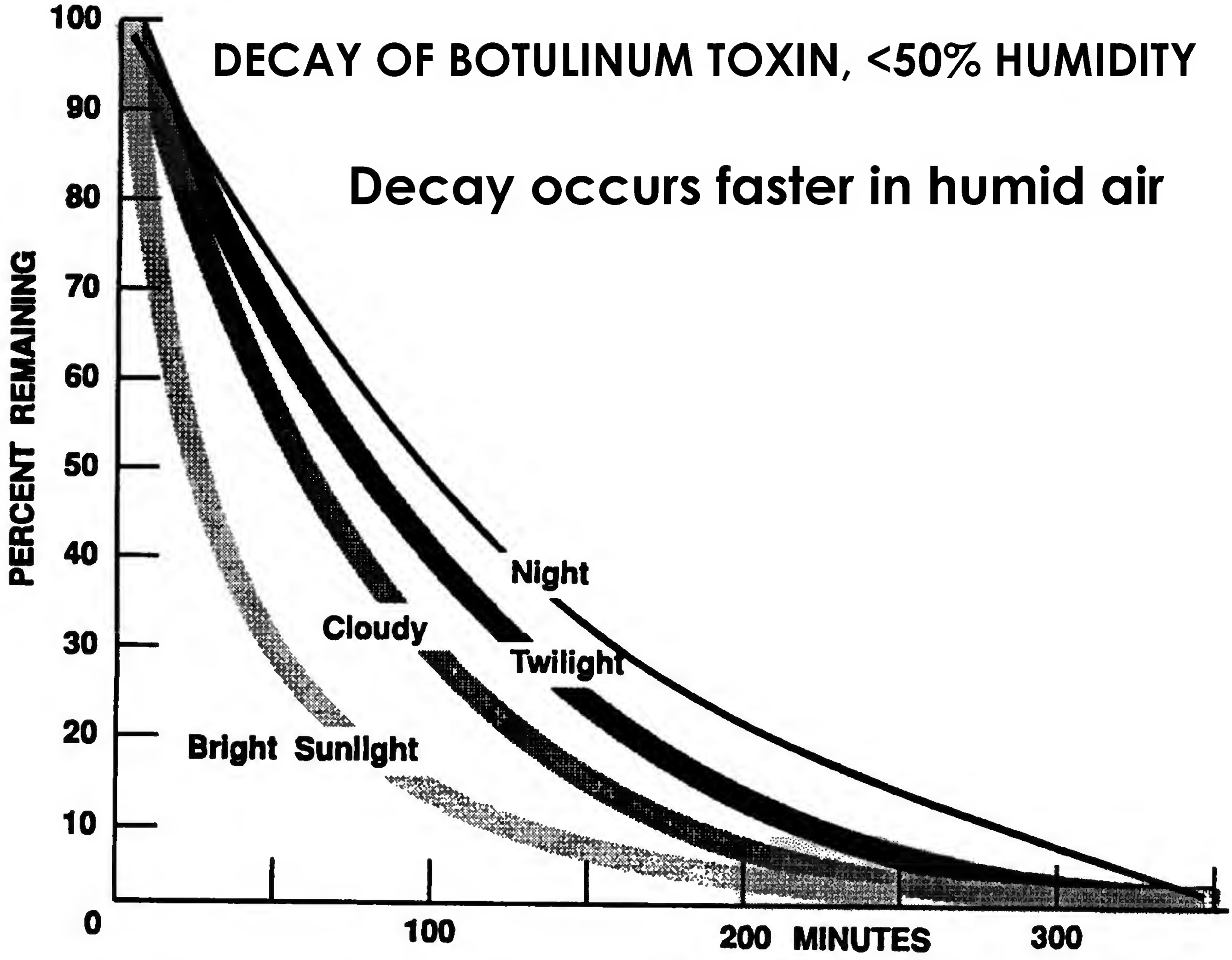
Field Purification of Water Contaminated by G Agents. Chemical Corps Medical Division Report No. 220, 1949. AD 212 449.

Field Tests of Protective Clothing Exposed to BW Aerosols. Chemical Corps Biological Laboratories, Special Report No. 112, August 1949.

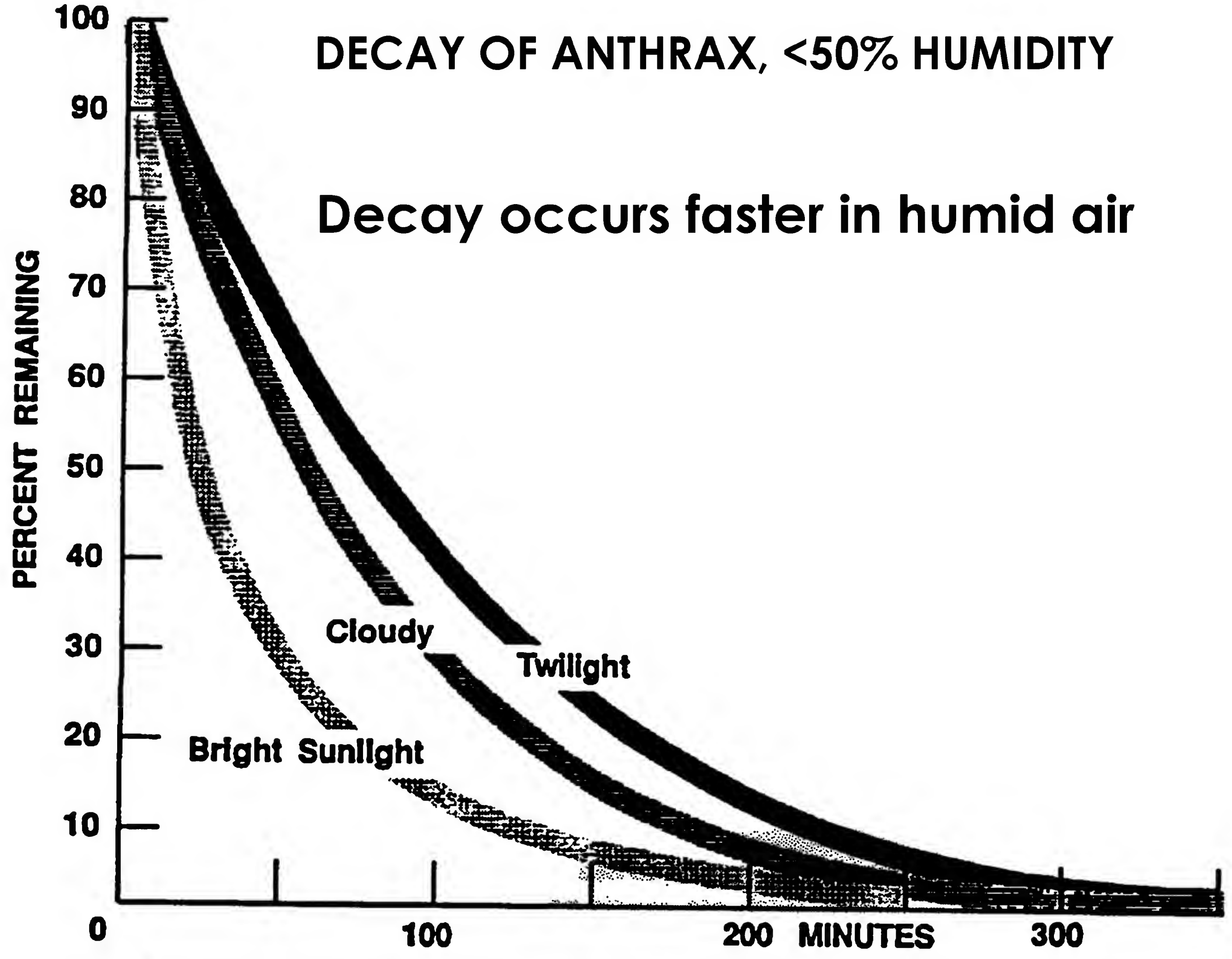
Possible Applications of Bacteriological Warfare to Public Water Supplies. Maloney, John R., Office of Naval Research, November 1959. AD 69 721, (CONFIDENTIAL).

Some Indications of Soviet Views on the Strategic Employment of CW/BW (U). Gouré, Leon, Rand Corporation, RM-2725, March 1961. (SECRET).

Studies on Insect Control (U). U.S. Army Engineer Research and Development Laboratories, Research Report 1656-RR, October 1960. AD 321 975, (CONFIDENTIAL).



U.S. Army Field Manual FM 3-3 (1992), Fig. B-3.



U.S. Army Field Manual FM 3-3 (1992), Fig. B-1.

- Basic decontamination procedures are generally the same no matter what the agent. Thorough scrubbing with large amounts of warm soapy water or a mixture of 10 parts water to 1 part bleach (10:1) will greatly reduce the possibility of absorbing an agent through the skin.

Sealing a Room

- Close all windows, doors, and shutters.
- Seal all cracks around window and door frames with wide tape.
- Cover windows and exterior doors with plastic sheets (6 mil minimum) and seal with pressure- sensitive adhesive tape. (This provides a second barrier should the window break or leak).
- Seal all openings in windows and doors (including keyholes) and any cracks with cotton wool or wet rags and duct tape. A water-soaked cloth should be used to seal gaps under doors.
- Shut down all window and central air and heating units.

Suggested Safehaven Equipment

- Protective equipment—biological/chemical rated gas masks, if available; waterproof clothing including long-sleeved shirts, long pants, raincoats, boots, and rubber gloves.
- Food and water—a 3-day supply.
- Emergency equipment—flashlights, battery-operated radio, extra batteries, can or bottle opener, knife and scissors, first aid kit, fire extinguisher, etc.
- Most chemical and biological agents that present an inhalation hazard will break down fairly rapidly when exposed to the sun, diluted with water, or dissipated in high winds.

United States Department of State Publication No. 11162
Bureau of Diplomatic Security
Reprinted July 2004

United States Department of State
Bureau of Diplomatic Security

Responding to a Biological or Chemical Threat

IN THE UNITED STATES

In 1995, the Aum Shinrikyo, a Japanese religious cult, launched a large-scale chemical attack on the Tokyo subway system. The attack focused on four stations using Sarin gas, a potent chemical warfare nerve agent. Twelve people were killed but the attack fell far short of the apparent objective to inflict thousands of casualties. Subsequent investigation by authorities revealed that the cult had previously conducted several unsuccessful attacks against a variety of targets using other chemical agents and the biological agents botulism toxin and anthrax.

More recently, the incidents of anthrax contamination in the United States served to illustrate the viability of this type of terrorist threat. Again, the attacks fell short of mass casualties, but some deaths did occur and the fear and disruption caused by a few positive anthrax findings were crippling. The U.S. Government continues working to meet the potential consequences of such attacks.

ORNL-6615

EVALUATING PROTECTIVE ACTIONS FOR CHEMICAL AGENT EMERGENCIES

by

G. O. Rogers
A. P. Watson
J. H. Sorensen
R. D. Sharp
S. A. Carnes

Date Published–April 1990

Prepared for the
U.S. DEPARTMENT OF THE ARMY
Office of the Assistant Secretary,
Installations, Logistics and Environment
under Interagency Agreement DOE No. 1769-1354-A1
and
FEDERAL EMERGENCY MANAGEMENT AGENCY
Office of Natural and Technological Hazards
under Interagency Agreement No. 1457-B106-A1

Prepared by the Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Lockheed Martin Energy Research
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

APPENDIX G
INSTRUCTIONS FOR IMPLEMENTING EXPEDIENT SHELTER IN CHEMICAL EMERGENCIES

Entering your dwelling or other buildings and following a few simple procedures can reduce exposure to released toxic chemical. These instructions can help you implement a series of actions to increase your protection. The series includes six basic steps:

1. preparing your dwelling to provide protection,
2. selecting an appropriate room within your dwelling to provide maximum shelter,
3. assembling the necessary materials needed to complete the procedures,
4. sealing a room within the dwelling to provide additional protection,
5. remaining in the shelter until notified that the hazard has passed, and
6. vacating the shelter upon plume passage.

Because each house is in some ways unique, you may need to adapt these procedures to your particular home. These instructions order the activities in terms of what is most important in obtaining maximum protection. Therefore, we recommend that you follow these steps in sequence wherever possible. Time is critically important to ensure adequate protection, so implement each step as quickly as you can without making mistakes and continue to the next step as soon as possible.

G.1. Preparing Your Dwelling

The objective is to prepare your dwelling to provide the maximum reduction of airflow from outside to inside. These preliminary steps also provide some protection while you carry out the procedures.

- 1a. Go or stay indoors.
- 1b. Close all exterior doors and windows (close storm windows if this can be done quickly). Don't forget garage doors in integral or attached garages as well as doors normally left open for ventilation.
- 1c. Close all interior doors.
- 1d. Turn off central heat/air conditioning fans, ceiling fans, kitchen hood fans, and circulating fans.

G.2. Selecting the Appropriate Room

The objective is to select the room that is best suited to reducing overall air infiltration while <u>having at least 10 square feet of floor area per person.</u> Under hot and humid conditions more space is advisable to avoid conditions that might lead to heat prostration within the shelter. Moreover, room air conditioners that recirculate internal

air may be used to create more comfortable shelter conditions. For example a 5×8 foot room has 40 ft^2, which would be appropriate for sheltering up to 4 people. This step can be completed in advance. If you have already preselected the room to provide maximum shelter, skip to Sect. G.3 below.

2a. The best room is a relatively small, has no outside walls, and is on the ground floor.
2b. If 2a is not available; select a small room with no windows.
2c. If 2a and 2b are not available: select the room with the smallest number of windows and doors.
2d. Avoid rooms with window air conditioners, windows that leak, vents to outside such as automatic dryer vents, and circulation vents.
2e. <u>Do not select rooms with exhaust vents that automatically start when the light is turned on</u>. These exhaust fans force external air into the room.
2f. If all the above elements are the same for two rooms, choose the room that is free of plumbing fixtures, because such fixtures increase the potential airflow and will require sealing as described in Sect. G.4 below.

G.3. Assembling Materials and Resources

This stage of the procedures is designed to collect all the needed materials to reduce the airflow as much as possible in the room you selected in Sect. G.2 above. This step can be performed ahead of time. Place the following materials in the selected room.

3a. the expedient shelter kit provided;
3b. verify that the kit still has the tape, plastic sheet, scissors, clay, and screwdriver;
3c. obtain a large towel (at least bath-towel size);
3d. a ladder, stool, or chair if required to seal any ceiling vents or the tops of windows and doors;
3e. a radio or television or other communication device (preferably portable) to let you to know when the plume has passed so you can exit at an appropriate time; and
3f. if the selected room does not have plumbing, drinking water and sanitary facilities (a covered bucket or other vessel containing approximately 1 cup of chlorine bleach).

G.4. Taping and Sealing

This set of procedures is designed to identify and seal the major sources of airflow between the room you have selected and the rest of the house, as well as restrict the flow of any toxic chemical that may be outside. These steps are sequenced to eliminate larger sources of air exchange first, so they should be implemented in the order listed whenever possible.

4a. Assemble people to be protected in the selected room and close the door. If windows were not closed as instructed in Sect. G.1 above, do so now.

4b. Jam the towel under the entire width of the door, sealing the whole area between the bottom of the door and the floor.

4c. VENTS: <u>If there are no vents, skip to step 4d below</u>. Locate any vents associated with the heating system, fan vents which are sometimes located in bathrooms, or vents to other rooms or to the outside such as dryer vents. Then, tape over small vents repeatedly, overlapping the tape to form a complete seal. For large vents, cut a piece of plastic sheeting large enough to cover the vent, place it over the vent, and tape the plastic loosely in place at the corners. Tape the plastic along each edge to ensure a complete seal. Repeat for each vent in the room.

4d. WINDOWS: <u>If there are no windows, skip to step 4e below</u>. If there are any broken or cracked windows, apply tape or cling-wrap over glass. Locate all leak points (any joints in the window frame, where movable parts of the frame come together), apply cling-wrap to each leak point. Then, cut a piece of plastic sheeting large enough to cover window and window frame, place it over the window and frame, and tape the plastic loosely in place at the corners. Tape the plastic along each edge to ensure a complete seal.

4e. Before you complete the seal on the door, check all supplies to ensure that you have enough material to completely seal the door. <u>Do not open the door unless you clearly have inadequate materials to complete the seal</u>; breaking the door seal will substantially reduce the protection provided by the refuge.

4f. DOOR: Tape along each edge of the door to seal off airflow, beginning with the parts you can reach from the floor and proceeding to the upper parts that may require the use of a ladder, stool, or chair. Place and tape cling-wrap over each hinge and the door handle.

4g. PLUMBING FIXTURES: <u>If there are no plumbing fixtures, skip to step 4h below</u>. Use putty or clay around all pipes that penetrate walls, ceiling, or floor (both intake and drainage pipes). To apply clay or putty, pull back the pipes decorative sealing ring (use screwdriver if necessary), wrap enough clay or putty around the pipe to fill any gaps between the wall and the pipe, and reset the decorative ring in clay by pressing the ring firmly against wall. Repeat for all pipe entry and exit points.

4h. CABINETS: <u>If there are no built-in cabinets such as sink cabinets, linen closets, or medicine cabinets, skip to step 4i below</u>. Close the cabinet doors and tape them closed according to the procedures described for doors in step 4f above. Note that, because cabinet hinges and handles are smaller than those on doors, tape will probably cover these areas adequately. Then, tape or use cling-wrap along all joints where the cabinet meets the wall. Pay particular attention to kickplates below cabinets, by checking the underside for holes and gaps. Smaller gaps may need to be plugged with clay.

4i. ELECTRICAL FIXTURES: Locate all electrical fixtures, including outlets, switch boxes, and lights. If a light is recessed or if it cannot be sealed without

turning it off, it will have to remain unsealed because covering a light without turning it off may start a fire. Put tape over the outlet boxes, and use cling-wrap or tape to cover all switch boxes. Put cling-wrap over light fixtures not in use. (Some light fixtures contain fans that run continuously with the light in the room. These fans should be turned off as early as practical; if they cannot be turned off, a different room should be selected as instructed in Sect. G.2 above.)

4j. CHECKING YOUR WORK: After, you have completed the procedures to seal the room you have selected, check each area you sealed by slowly passing your hand in front of all potential leak areas. If you can feel air flowing, try to seal it better. We do not recommend that you remove any previous seals, but you may want to add plastic sheeting over sealed areas or tape them more securely.

G.5. Remaining in Shelter

The objective of this stage is to relax as much as possible and wait to be notified of the appropriate time to exit the shelter.

5a. Shelter occupants should be as comfortable as possible; they should stand or move around as little as possible.
5b. Remain calm and relax; doing so adds additional protection by reducing your respiration rate.
5c. Turn on communication device so you can be contacted when it is safe to exit the shelter.
5d. Ask each occupant to periodically check for airflows near them. If any are discovered, seal them by following the above procedures.
5e. Wait for notification of plume passage.

G.6. Vacate Shelter

The objective of this step is to exit the shelter when the plume passes by and to avoid any further cumulative exposure.

6a. Put on protective clothing.
6b. Open all windows and doors.
6c. Evacuate to reception center for medical evaluation and decontamination.

EXPEDIENT SHELTER INSTRUCTION CHECKLIST

1. Prepare your dwelling to provide protection.

1a. Go or stay indoors.
1b. Close all exterior doors and windows.
1c. Close all interior doors.
1d. Turn off fans.

2. Select an appropriate room within your dwelling to provide maximum shelter, <u>having at least 10 square feet of floor area per person</u>.

2a. Choose a relatively small room with no outside walls on the ground floor.
2b. If not available: select a small room with no windows.
2c. If not available: select the room with the fewest windows and doors.
2d. Avoid rooms with window air conditioners, windows that leak, vents to the outside, and circulation vents whenever possible.
2e. Avoid rooms with plumbing fixtures whenever possible.

3. Assemble the necessary materials.

3a. Use the expedient shelter kit provided;
3b. Verify that its contents are complete;
3c. Large towel of at least bath-towel size;
3d. Ladder, stool, or chair if necessary;
3e. Radio, television, or other communication device;
3f. Drinking water and covered container with chlorine bleach for sanitary purposes.

4. Seal a room in the dwelling to provide additional protection.

4a. Enter the selected room and close the door.
4b. Jam the towel under the door.
4c. Seal vents.
4d. Seal windows.
4e. Check all supplies; replace if necessary.
4f. Seal door.
4g. Seal plumbing.
4h. Seal cabinets.
4i. Seal electrical fixtures.
4j. Check you work; reseal where necessary.

5. Remain in the shelter until notified that the plume has passed.

5a. Get as comfortable as possible.
5b. Remain calm, relax, and stay immobile.
5c. Turn on communication device.
5d. Periodically check for airflows in the shelter.
5e. Wait for notification of plume passage.

6. Vacate shelter.

6a. Don protective clothing.
6b. Open all windows and doors.
6c. Evacuate.

ORNL/TM-2001/153

Energy Division

Expedient Respiratory and Physical Protection: Does a Wet Towel Work to Prevent Chemical Warfare Agent Vapor Infiltration?

John H. Sorensen
Barbara M. Vogt

Date Published—August 2001

Prepared for the
Federal Emergency Management Agency
Chemical Stockpile Emergency Preparedness Program

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

1. INTRODUCTION

Several public information efforts in the Chemical Stockpile Emergency Preparedness Program (CSEPP) advocate the use of wet towels to (1) seal a door jam against the infiltration of chemical vapors and (2) provide expedient respiratory protection.

A wet towel has been a common respiratory protection practice for fires to reduce inhalation of soot and smoke, but will this strategy protect against chemical vapors? Using a wet towel to reduce infiltration of chemicals into a room by sealing the gap between the floor and the door is frequently cited in the shelter-in-place (SIP) literature (see Blewett et al. 1996).

The purpose of this paper is to examine the effectiveness of such measures to reduce exposure to vapors from chemical warfare agents. This evaluation includes an examination of the physical and the psychological effectiveness of these measures. Little research has been conducted to examine the effectiveness of expedient protection against chemical vapors and aerosols. More is known about the penetration of aerosols than vapor. In this paper, we summarize the research to date and offer several recommendations for CSEPP.

2. PREVIOUS RESEARCH ON EXPEDIENT PROTECTION

The first documented research on expedient respiratory protection was conducted by Guyton et. al. (1959). They performed a series of tests to determine whether common household items provided respiratory protection against a release of radiological or biological aerosols. The materials they tested included

- a man's cotton handkerchief,
- a women's cotton handkerchief,
- cotton clothing material,
- muslin bed sheet,
- cotton shirt,
- rayon slip,
- cotton terry bath towel, and
- toilet paper.

In total, 18 variations of the 8 materials were tested. The tests performed used human subjects who inhaled *B. globigii* (a bacteria aerosol) through the various materials into a mouthpiece collector. The results of the testing indicated that 5 of the variations had filtration efficiency of greater than 85%. These included a folded (16 and 8 thickness) or crumpled handkerchief, 3 thickness of toilet paper, and a bath towel folded in half. Tests

were performed on wetted items, but the efficiency was lower than for dry items. In addition, only the bath towel was feasible to breath through when wet. No testing for vapor protection was performed.

A series of experiments was performed by the Harvard School of Public Health in the early 1980's (Cooper, Hinds, and Price 1981; 1983; Cooper et al. 1983a,b; Price, Cooper, and Yee 1985). These efforts sought to build on the work of Guyten et al. by examining the penetration of expedient materials by particle size and by examining penetration by vapors. Materials similar to those in the earlier studies were used; but instead of human subjects, several test chambers were designed. Mineral oil was used for the aerosol tests and methyl iodide and iodine were used in the vapor tests. Methyl iodide is a difficult vapor to capture, while iodine, a highly reactive gas, was chosen because it is readily removed by wet filtration, thus setting the upper boundary for effectiveness against a gas.

The first set of tests examined the effectiveness of the materials in filtering the aerosols and vapors. For aerosols, the reductions by a factor of 30 were achieved with the dry materials across the range of aerosol sizes. Reductions by a factor of five were achieved with wet materials. No filtration was achieved with dry materials for both vapors. As predicted, wet materials had no effectiveness for methyl iodide but were effective in filtration of iodine vapors (60 % filtration) (Cooper, Hinds, and Price 1981; 1983).

Additional experiments were performed using a manikin to evaluate aerosol leakage around the protective materials assessed in the first experiments. These tests showed that the leakage rates around the edges of the expedient materials (in addition to the leakage of the materials), ranged as high as 63%. The study concluded that holding expedient materials over the face would not provide significant protection against aerosols due to the leakage problem. The study also concluded that some material, such as a panty hose, was needed to secure the expedient protective materials around the mouth and nose in order to minimize leakage (Cooper et al. 1983a,b). Although vapors were not included in this study, it is reasonable to assume that leakage around the perimeters of the materials would also be problematic for vapors.

Additional tests were performed with aerosols in the extremely small particle size range (Price, Cooper, and Yee 1985). These tests, as with the other aerosol tests, are not relevant for civilian protection in CSEPP SIP actions because of the extremely low likelihood of aerosol contamination off-post.

A major concern in all studies was the ability to inhale through the expedient materials. This proved problematic for all wet materials except for wet toweling. For the thick dry materials, such as the folded handkerchief—which was the most effective filter, breathing comfortably would be possible for only short periods of time.

Additional work on the effectiveness of expedient protection against chemical warfare agent simulants was conducted as part of a study on chemical protective clothing materials (Pal et al. 1993). Materials included a variety of chemical-resistant fabrics and duct tape. The materials were subject to liquid challenges by the simulants DIMP (GB

simulant), DMMP (VX simulant), MAL (organoposphorous pesticide), and DBS (mustard simulant). The study concluded that "Duct tape exhibits reasonable resistance to permeation by the 4 simulants, although its resistance to DIMP (210 min) and DMMP (210 min) is not as good as its resistance to MAL (>24 h) and DBS (> 7 h). Due to its wide availability, duct tape appears to be a useful expedient material to provide at least a temporary seal against permeation by the agents" (Pal et al. 1993, p. 140).

3. ADDITIONAL CONSIDERATIONS

Expedient respiratory protection may have social-psychological benefits as well as problems that need to be examined as well.

Problems

Expedient respiratory protection can cause or exacerbate problems by

- deterring oral communications among a family in a sheltered room and communications are very important in a SIP situation,
- deterring taping a room if people attempt to use expedient respiratory protection from the onset of SIP,
- being an additional resource for a SIP kit or materials that would need to be located at the time of a SIP warning,
- hampering driving ability during evacuation because of impairment of hand use and possible visual difficulty, and
- causing hyperventilation in some people with a tendency to be claustrophobic about impediments to breathing.

Benefits

Expedient respiratory protection can also

- have a placebo effect, making people believe they are safe while they are in a SIP and
- reinforcing the concept of proactive protection during SIP.

Overall, it appears that the non-physical benefits of expedient respiratory protection do not exceed the potential problems. However, it will be important to communicate to the public that expedient respiratory protection is beneficial in other emergency situations (such as a fire or for volcanic ash).

4. RECOMMENDATIONS FOR CSEPP

Respiratory protection for civilians has never been considered a viable option for population protection in the CSEPP. Problems of storage, ability to effectively don respirators, and questionable fit have been primary factors in rejecting this option. Expedient respiratory protection seems to offer little benefit for population protection.

Because chemical warfare agent vapors are not reactive with water—or, in some cases, not very soluble, even if easily hydrolyzed (Munro et al. 1999)—it is unlikely that wetted towels will provide significant respiratory protection while a person is sheltering in place. In no case would it be recommended that people attempt to evacuate through a vapor plume with or without expedient respiratory protection. Because of the physical ineffectiveness of the practice and the fact that the social-psychological benefits do not outweigh the social-psychological problems, we recommend that expedient respiratory protection should not be used in CSEPP protective action strategies.

Furthermore, we believe that using wet towels as a vapor barrier at the bottom of a door should be discouraged in favor of using duct tape to seal the bottom of doors. A wet towel provides no vapor filtration; and while it will reduce infiltration, its effectiveness in doing so is not known. A towel wetted with a 0.5% solution of hypochlorite (a 1:9 dilution of household bleach) may provide some protection. A hypochlorite solution is an effective decontaminant for nerve agent vapors and would provide dual protection, both physical and chemical (Munro et al. 1990). Taping the bottom of the door will still likely provide greater infiltration reduction and is recommended as the current method for use in SIP for CSEPP.

5. ACKNOWLEDGEMENTS

The authors thank Rob Weiss and Bill Blewett, Soldier and Biological Chemical Command, and Nancy Munro, Oak Ridge National Laboratory, for their comments on the draft of this paper.

6. REFERENCES

Blewett, W. K., D. W. Reeves, V. J. Arca, D. P. Fatkin, and B. D. Cannon 1996. *Expedient Sheltering in Place: An Evaluation for the Chemical Stockpile Emergency Preparedness Program*, ERDEC-TR-336, Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, Md.

Cooper, D. W., W. C. Hinds, and J. M. Price 1981. *Expedient Methods of Respiratory Protection,* NUREG/CR-2272, Sandia National Laboratory, Albuquerque, N.M

Cooper, D. W., W. C. Hinds, and J. M. Price 1983. "Emergency Respiratory Protection with Common Materials," *Am. Ind. Hyg. Assoc. J.* **44**(1):1-6.

Cooper, D.W., W. C. Hinds, and J. M. Price, R. Weker, and H. S. Yee 1983a. "Common Materials for Emergency Respiratory Protection: Leakage Tests with a Manikin," *Am. Ind. Hyg. Assoc. J.* **44**(10):720-26.

Cooper, D. W., W. C. Hinds, J. M. Price, R. Weker, and H. S. Yee 1983b. "Expedient Methods of Respiratory Protection II: Leakage Tests," NUREG/CR-2958, Sandia National Laboratory, Albuquerque, N.M.

Guyton, N. G., H. M. Decker, and G. T. Anton 1959. "Emergency Respiratory Protection Against Radiological and Biological Aerosols," *A.M.A. Arch. Ind. Hlth.* **20**(Aug.):91-95.

Munro, N. B., A. P.Watson, K. R. Ambrose, and G. D. Griffin 1990. "Treating Exposure to Chemical Warfare Agents: Implications for Health Care Providers and Community Emergency Planning," *Env. Hlth. Persp.* **89**: 205-15.

Munro, N. B., S. S. Talmage, G. D. Griffin, L. C. Waters, A. P. Watson, J. F. King, and V. Hauschild 1999. "The Sources, Fate, and Toxicity of Chemical Agent Degradation Products," *Env. Hlth. Persp.* **107**:933-974.

Pal, T., G. D. Griffin, G. Miller, A.P. Watson, M. L. Doherty, and T. Vo-Dinh 1993. "Permeation Measurements of Chemical Agent Simulants Through Protective Clothing Materials," *J. Haz. Mat.* **33**:123-41.

Price, John M., Douglas W. Cooper, and H. S. Yee 1985. "Expedient Methods of Respiratory Protection III: Submicron Particle Tests and Summary of Quality Factors," NUREG/CR-3537, Sandia National Laboratory, Albuquerque, N.M.

FM 3-10

DEPARTMENT OF THE ARMY FIELD MANUAL

CHEMICAL AND BIOLOGICAL WEAPONS EMPLOYMENT

HEADQUARTERS, DEPARTMENT OF THE ARMY
FEBRUARY 1962

FIELD MANUAL No. 3-10

HEADQUARTERS,
DEPARTMENT OF THE ARMY
WASHINGTON 25, D.C., *20 February 1962*

CHEMICAL AND BIOLOGICAL WEAPONS EMPLOYMENT

CHAPTER 1

INTRODUCTION

1. Purpose

This manual provides guidance to commanders and staff officers in the employment of chemical and biological weapons. It contains a brief summary of background knowledge of chemical and biological agents and munitions and the procedures to be followed in planning their employment.

2. Scope

a. General. Considerations are limited to chemical and biological agents and delivery systems that are type-classified or expected to be type-classified during the period ending December 1965. The chemical agents are nerve agent GB, nerve agent VX, and blister agent HD. The agent delivery means are artillery and mortar shells, rocket and missile warheads, aircraft bombs, and spray devices. FM 3–10A contains the classification and characteristics of biological agents and information on biological munitions and delivery systems. Troop safety considerations are presented. This manual is applicable to nuclear and nonnuclear warfare.

b. Chemical Agents. Chapters 3 through 8 contain a discussion of chemical agents and their characteristics; factors affecting the employment of chemical agents; chemical munitions and delivery systems and the concepts for their employment; and target analysis, fire planning, and logistical considerations. Methods of chemical target analysis presented are suitable for fire planning and casualty assessment at all echelons of command having chemical fire planning and assessment responsibilities.

c. Biological Agents. Chapters 9 through 13 contain a discussion of biological agents and their characteristics; factors affecting the employment of biological agents; biological munitions and delivery systems and the concepts of their employment; and target analysis, effects assessments, and logistical considerations. Only the antipersonnel effects of biological agents are considered. The methods of biological weapons target analysis presented are suitable for biological fire planning and casualty assessment. The unique character of biological munitions supply and field management is presented.

d. Reliability. The data and procedures presented in this manual have been extracted or derived from official studies and from research and development documents. The potential performance of materiel is based on field trial data with simulants and selected live agents and on theoretical calculations and assumptions developed from mathematical models. The procedures are therefore subject to change as may be required by future developments or refinements. It should be noted that the flow of a chemical or biological agent cloud over the terrain cannot be predicted with a high degree of precision. This is due principally to the inability to predict accurately the prevailing atmospheric conditions of the area under consideration with respect to the diffusion and dissipation of an agent cloud. Nevertheless, the methods and procedures presented here provide information with sufficient accuracy to be used with reasonable confidence.

e. User Comments. Users of this manual are encouraged to submit recommended changes or comments to improve the document. Comments should be keyed to the specific page, paragraph, and line of the text in which change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded direct to the Commandant, U.S. Army Chemical Corps School, Fort McClellan, Ala.

3. The Role of Chemical Agents in Military Operations

a. Chemical weapons increase the flexibility of the integrated weapons systems and place at the commander's disposal a highly effective means of conducting antipersonnel operations.

b. In the conduct of military operations involv-

ing chemical weapons, some factors that should be considered are—

(1) The chemical agents discussed herein do not destroy materiel. On the contrary, they allow the physical preservation of industrial complexes, cultural institutions, lines of communications, and other facilities and materiel that may be useful to friendly forces or that merit preservation for political or economic reasons.

(2) Chemical munitions do not produce physical obstacles to maneuver, since they cause minimal destruction, blowdown, rubble, and similar barriers. Agents that produce a persistent effect, however, will create a hazard to friendly troops.

(3) Chemical agents may be employed to produce a variety of effects ranging from harassment to lethality.

(4) Toxic chemical clouds penetrate fortifications and similar structures that are not airtight.

(5) Because of their area coverage effect, chemical agents, used in mass, are particularly effective in attacking targets whose location is not precisely known.

(6) Chemical munitions are particularly effective for producing casualties among dug-in personnel who are not provided with chemical protection.

(7) Chemical agents increase the flexibility of the entire spectrum of firepower available to the commander.

(8) Chemical agents may be used to follow up and exploit advantages gained by other means.

(9) Because the effectiveness of chemical agents on the target is influenced by the type and quantity of agent employed and by the method of dissemination, meteorological factors, conditions of the target, and protection and training of enemy troops, it is difficult to predict the results of employment accurately.

(10) Chemical agents may produce hazards to friendly forces because of residual contamination and cloud movement.

4. Chemical Agents

a. The following three type-classified chemical agents provide commanders flexibility in their employment of chemicals.

(1) Nerve agent GB is a rapid-acting lethal agent that is used primarily for respiratory effects against unprotected personnel and for surprise attack against personnel having masks available.

(2) Two agents are used in circumventing the protective mask.

(*a*) VX is a slow-acting lethal nerve agent when absorbed percutaneously. If inhaled as an aerosol or vapor, VX acts as rapidly as GB and is more toxic.

(*b*) HD is a slow-acting casualty agent with a limited lethal effect. It attacks the skin in liquid or vapor form and is also effective by inhalation.

b. The following figures describe GB and HD in more detail. Detailed information on VX is contained in FM 3–10A. More comprehensive data on chemical agents are in TM 3–215.

1. Primary use	Nonpersistent, rapid-acting lethal agent used primarily for respiratory effect.
2. Average time to incapacitation	15 minutes after exposure to an incapacitating dosage; for lethal dosages, death in 5 minutes after appearance of symptoms if untreated.
3. Duration of incapacitation	1 to 5 days for return to duty. (30 to 60 days for return to normal blood cholinesterase level.)
4. Signs and symptoms	Tightness of chest, pinpointing of eye pupils, dimness of vision, excessive sweating, drooling; followed by tension, giddiness, tremors, confusion, slurred speech, weakness, convulsions, and death.
5. Physiological effects	Nerve poison; slow detoxification by body (60 days); effects of successive small dosages considered cumulative for short periods of time (weeks).
6. Route of entry	Inhalation; percutaneous entry by liquid or high vapor concentration is unlikely in the field because of the high dosage required.
7. Protection	Mask against vapor; protective clothing against liquid agent.
8. Limitations	Mask offers adequate protection against vapor for trained and warned personnel.
9. Duration of hazard	The area in and around shell or bomb craters will be contaminated and will remain a hazard to unprotected personnel for periods ranging from 6 hours to several days.
10. Physical properties	Clear, colorless, odorless liquid; freezing point minus 56° C (−69° F.); boiling point 147° C (297° F.); evaporates at approximately the same rate as water.

Figure 1. Characteristics of nerve agent GB.

1. Primary use — To cause delayed casualties by liquid and vapor effect on the skin and eyes and by vapor effect through the respiratory system.
2. Average time to incapacitation — Eye effect 3 to 12 hours; skin effect 3 to 24 hours.
3. Duration of incapacitation — Eye effect 1 to 7 days; skin effect 1 to 4 weeks.
4. Signs and symptoms — Inflammation of eyes; redness of skin; blistering; ulceration.
5. Physiological effects — Produces blisters and destroys tissues.
6. Route of entry — Skin absorption of vapor or liquid and inhalation of vapor.
7. Protection — Mask, ointment, and protective clothing.
8. Limitations — Limited effectiveness in freezing weather; greater dosages are required for casualty production than are required with GB or VX.
9. Duration of hazard — 36 hours to several days. See figure 2.1d.
10. Physical properties — Clear oily liquid with garliclike odor; moderately volatile; freezing point 14° C. (57° F.); boiling point 228° C. (442° F.).

Figure 2. Characteristics of blister agent HD.

Times given indicate approximate time after contamination that personnel may operate in the area

Task	Terrain	Protection (Based on expenditures between 240 and 1,200 pounds of HD per hectare) — With protective clothing and wearing masks — Temperature — 16°–27° C. (60°–80° F.)	With protective clothing and wearing masks — Temperature — Above 27° C. (80° F.)	Without protective clothing[1] — Temperature — 16°–27° C. (60°–80° F.)	Without protective clothing[1] — Temperature — Above 27° C. (80° F.)
		Hours	*Hours*	*Days*	*Days*
TRAVERSAL[2] (Walking across area up to 2 hr)	Bare soil, sand, or short grass	0	0	[3] 1½	[3] 1½
	Low vegetation	4	2	[3] 1½	[3] 1½
	High vegetation, including jungle and heavy woods.	12	6	[3] 4	[3] 2
ADVANCE UNDER FIRE (Contact with ground, 1 hr; total time in area, 2 hr).	Bare soil or low vegetation	24	8	[3] 3	[3] 2
	High vegetation, including jungle and heavy woods.	48	24	[3] 6	[3] 4
OCCUPATION (Without hitting ground, 24 hr)	Bare soil or low vegetation	1	1	[4] 4	[4] 3
	High vegetation, including jungle and heavy woods.	1	1	[4] 4	[4] 3
OCCUPATION (Involving advance under fire, 24 hr).	Bare soil or low vegetation	24	8	[4] 4	[4] 3
	High vegetation, including jungle and heavy woods.	48	24	[4] 6	[4] 4

[1] For men walking in a contaminated area for 2 hours without protective clothing, the limiting factor is the vapor.
[2] For men with protective clothing, when traversal is made in daylight and areas of heavy contamination can be avoided or decontaminated, the times can be reduced to about one-half of those indicated above.
[3] Wearing masks.
[4] Not wearing masks.

Figure 3. Duration of HD hazard in target area.

Additional micrometeorological characteristics of the zone of operations are obtained through the following methods:

(1) Aerial reconnaissance and observations.
(2) Ground reconnaissance and observations.
(3) Observations of fog, smoke, and dust in the zone of operations.
(4) Field expedient methods for obtaining micrometeorological data in the vicinity of the target area.
(5) Statistical studies of weather in the theater of operations.

b. A suggested format for transmission and recording of basic weather data is illustrated in appendix II. It is emphasized that in chemical target analysis, the weather predictions are required for a period of time after the attack as well as for the time of the chemical attack.

c. Normally, Air Weather Service detachments are stationed at field army, corps and division headquarters. From these sources a target analyst may obtain weather data and weather briefings, or he may request detailed operational and planning forecasts and climatological information.

10. Temperature

The rate of evaporation of chemical agents increases as the temperature rises. High temperatures cause personnel to perspire more freely, thus opening the pores of the skin and accelerating penetration of the skin by the agent. At low temperatures, extra layers of clothing increase the barrier to the skin.

11. Temperature Gradient

The temperature gradient is an expression of the difference in air temperature at two levels. In the United States Army, it is determined by subtracting the air temperature (Fahrenheit) measured one-half meter above the ground from the air temperature 2 meters above the ground. The three characteristic conditions that are associated with the temperature gradient follow:

a. Lapse. A decrease in air temperature with an increase in height is known as a *lapse* condition. Such a condition normally exists on a clear or partially clear day and is characterized by heat turbulence. It is the least desirable condition for chemical operations because of rapid dissipation of agent clouds.

b. Inversion. An increase in air temperature with an increase in height is known as an *inversion* condition. This condition exhibits a minimum of turbulence and usually exists on a clear or partially clear night or early morning. This is the most desirable condition for chemical operations since the agent cloud tends to remain in the cooler layers of the air near the ground.

c. Neutral. A condition intermediate between lapse and inversion is known as a *neutral* condition. Such a condition prevails when there are small differences in temperature at the two levels and usually exists on heavily overcast days or nights, and shortly after sunrise and near sunset.

12. Wind

The wind is also an important weather element affecting the field behavior of chemical clouds. Of the wind characteristics, velocity and direction have greatest influence. Both characteristics are influenced by terrain and temperature gradient.

a. Velocity. Air moving over an irregular surface sets up eddies, or mechanical turbulence. This turbulence is similar to heat turbulence in that it acts to dissipate a chemical cloud. High wind velocities also cause the agent cloud to pass rapidly over the target area, thus reducing the exposure time. Some air movement is desired to blend the individual clouds of agent formed by each shell burst into a uniform cloud covering the target. Ideal wind velocities for chemical operations are 3 to 9 knots (approximately 6 to 16 kilometers per hour). Wind velocities in excess of 16 knots (approximately 30 kilometers per hour) are not suitable for nonpersistent effects.

b. Direction. Wind directs the travel of a chemical cloud. This fact must be considered in the release of an agent for coverage of a particular target and in the determination of the downwind hazard to friendly troops. The wind direction is the direction from which the wind blows and is expressed in terms of azimuth in mils or degrees.

13. Precipitation

Precipitation has an adverse effect on the behavior of chemical agents, since rain will wash away the liquid agent contamination and snow will cover it. Precipitation also washes agent vapors or aerosol clouds from the air and destroys some agents by hydrolysis.

Line	1 Munition	2 Agent	3 Delivery system	4 User	5 Employment data (a) Range (1) (Meters) (2) Maximum	 Minimum	 (b) Error	 (c) Fuze (Capability)
1	Shell, M2A1	HD	4.2-inch Mortar	US ARMY USMC	3, 930	180	←Obtain from delivery unit or appropriate firing tables→	M8PD
2	Shell, M360	GB	105-mm Howitzer, M2A1, M2A2, M4, M4A2, M52.	US ARMY USMC	11, 140	862		M508PD
3	Shell, M60	HD	105-mm Howitzer, M2A1, M2A2, M4, M4A2, M52.	US ARMY USMC	11, 140			M51A5PD
4	Shell, M121	GB	155-mm Howitzer, M1, M1A1, M44.	US ARMY USMC	14, 950			M508PD
5	Shell, M110	HD	155-mm Howitzer, M1, M1A1, M44.	US ARMY USMC	14, 950			M51A5PD
6	Shell, T__(M121)	VX	155-mm Howitzer, M1, M1A1, M44.	US ARMY USMC	14, 950			T76E6VT [1]
7	Shell, M122	GB	155-mm Gun, M2, M53	USMC	23, 500			M508PD
8	Shell, M104	HD	155-mm Gun, M2, M53	USMC				M51A5PD
9	Shell, Gas, 175-mm	GB	M107 Gun (SP)	US ARMY	31, 500	180		
10	Shell, Gas, 175-mm	VX	M107 Gun (SP)	US ARMY	31, 500	180		VT-M514A1
11	Shell, T174	GB	8-inch Howitzer, M2, M2A1, M55.	US ARMY USMC	16, 930			M51A5PD
12	Shell, T174	VX	8-inch Howitzer, M2, M2A1, M55.	US ARMY USMC.	16,930			T2061VT
13	Rocket, M55, 115-mm (BOLT)	GB	Launcher, M91	US ARMY USMC.	10,970	2,740		M417PD
14	Rocket, M55, 115-mm (BOLT)	VX	Launcher, M91	US ARMY USMC.	10,970	2,740		T2061VT
15	Warhead, M79, 762-mm (HONEST JOHN).	GB	Rocket, M31A1C Launcher, M386.	US ARMY USMC.	24,960	8,500		T2075 Mech Time
16	Warhead, E19R2, 762-mm (HONEST JOHN).	GB	Rocket, XM50 Launcher, M386.	US ARMY USMC.	33,830	8,500		T2075 Mech Time
17	Warhead, E19R2, 762-mm (HONEST JOHN).	VX	Rocket, XM50 Launcher, M386.	US ARMY USMC.	33,830	8,500		T2075 Mech Time
18	Warhead, E20, 318-mm (LITTLE JOHN).	GB	Rocket, XM51 Launcher, XM80.	US ARMY USMC.	18,290	3,200 [1]		T2075 Mech Time
19	Warhead, E21, (SERGEANT)	GB	Rocket, Launcher	US ARMY	139 km	50 km	304m	Preset Radar
20	Warhead, E21, (SERGEANT)	VX	Rocket, Launcher	US ARMY	139 km	50 km	304m	Preset Radar
21	Bomb, M34A1, 1000-lb, Cluster	GB	Fighter, Bomber	USAF	Range of Aircraft.		←Obtain from delivery unit→	M152E3 Mech Time
22	Bomb, MC-1, 750-lb	GB	Fighter, Bomber	USAF	Range of Aircraft.			M905BD
23	Projectile, 5"/38, MK53, MOD O	GB	5-inch Gun	US NAVY	16,450			MK29MOD3PD
24	Projectile, 5"/54, MK54, MOD O	GB	5-inch Gun	US NAVY	19,200			MK30MOD3PD
25	Warhead, Rocket, 5" MK40, MOD O.	GB	Launcher, MK 105 Rocket, M40, MOD O.	US NAVY	4,200			MK30MOD3PD
26	Warhead, Rocket, 5", MK40, MOD O.	HD	Launcher, MK 105 Rocket, M40, MOD O.	US NAVY	4,200			MK30MOD3PD
27	Bomb, MK94, MOD O	GB	Fighter, Bomber	US NAVY	Range of Aircraft.			AN-M103A1ND M195 BD (IMPACT).
28	Bomb, M70A1	HD	Fighter, Bomber	US NAVY	Range of Aircraft.			AN-M158ND (IMPACT).
29	Mine, Land, Chemical, M23	VX	N/A	US ARMY	N/A	N/A	N/A	
30	Mine, Land, Chemical, One-Gallon.	HD	N/A	US ARMY	N/A	N/A	N/A	

See notes at end of figure.

Figure 5. Chemical munitions and delivery systems.

5 Employment data—Continued						6 Functioning and physical characteristics of CML munitions				
(d) Time for delivery		(e)	(f)	(g)	(h)	(a)	(b)	(c)	(d)	(e)
(1) Preplanned	(2) Target of opportunity	Organization	Rate of fire per weapon	Height of burst	Diameter (meters) of impact area (single rd) [2]	Weight of munition (kg)	Weight of agent (kg)	Effective weight of agent (kg) [3]	Functioning efficiency of munition (percent)	Agent dissemination efficiency
		6 Mort/Plt 8 Mort/Btry	30 Rds/2 min 105 Rds/15 min	GND	16	10.8	2.72		99	
	1–3 min	6 How/Btry	6 Rds/½ min 18 Rds/4 min	GND	27	16.1	.739		99	
	1–3 min	6 How/Btry	6 Rds/½ min 18 Rds/4 min	GND	11	15.2	1.22		99	
	1–5 min	6 How/Btry	3 Rds/½ min 12 Rds/4 min	GND	49	45.9	2.95		99	
	1–5 min	6 How/Btry	3 Rds/½ min 12 Rds/4 min	GND	20	42.0	4.4		99	
	1–5 min	6 How/Btry	3 Rds/½ min 12 Rds/4 min	20m [1]		45.9	2.95		99	
	1–5 min	4 Gun/Btry	2 Rds/½ min 8 Rds/4 min	GND	49	45.9	2.95		99	
	1–5 min	4 Gun/Btry	2 Rds/½ min 8 Rds/4 min	GND	22	43.0	5.31			
		4 Gun/Btry		GND		66.8	6.68			
		4 Gun/Btry		GND		66.8	6.04			
	½–6 hr	4 How/Btry	6 Rds/4 min 10 Rds/10 min	GND	76	97.0	7.12		99	
	½–6 hr	4 How/Btry	6 Rds/4 min. 10 Rds/10 min.	20m [1]		97.0	7.12		99	
	30 min	36 Lchr/Bn	45 Rkt/Lchr/15 sec.	GND	46	26.4	4.80		99	
	30 min	36 Lchr/Bn	45 Rkt/Lchr/15 sec.	20m [1]		26.2	4.54		99	
	15 min	2 Lchr/Bn	2/Hr	Variable	Variable	737	177.5	104.8	95	62 percent.
	15 min	2 Lchr/Btry	2/Hr	Variable	Variable	568	210	171	95	86 percent.
	15 min	2 Lchr/Btry	2/Hr	Variable	Variable	568	210			
	15 min	4 Lchr/Btry	2/Hr	Variable	Variable	119	30			
15 min	120 min	4 Lchr/Bn	2/Day	Intervals of 1,524m.	Variable	744	190			
15 min	120 min	4 Lchr/Bn	2/Day	Intervals of 1,524m.	Variable	744	190			
	15 min +flight time.		2–6/Ftr 4–18/Bmbr.	Variable	170	513	89.6		90	
	15 min +flight time.		2–6/Ftr 4–27/Bmbr.	GND	127	322	99.9			
				GND	35	25.1	1.47			
				GND	40	29.1	2.02			
			48 Rkt/Lchr/ 1 min	GND	49	22.9	2.18			
			48 Rkt/Lchr/ 1 min	GND						
				GND	90	222	49.8			
				GND	29	58.0	272			
						10.50	5.23			
						5.45	4.50			

[1] Estimated.

[2] Instantaneous agent area coverage 30 seconds after detonation.

[3] Values are the product of values given in columns 6(*b*), 6(*d*), and 6(*e*). Since values for 6(*e*) are not available, values for 6 (*c*)cannot be computed at this time.

Figure 5.—Continued

Agent—GB.
Wind speed—5 knots (approx 9 km/hr).
Temperature gradient—inversion.
Temperature—60° F. (15.5° C.).
Terrain—open, level, scattered vegetation.
Precipitation—none.
Time limitations on the delivery of agent on target—4 minutes or less.
Casualty level desired—20 percent.

Find: Whether or not the mission can be fired with a 105-mm howitzer battery.

Solution:

(*a*) Using figure 11, convert 20 percent casualties among protected personnel to the corresponding casualty level among unprotected personnel. This is 80 percent.

(*b*) Using the "GB (over 30-sec attack)" column of figure 12, determine the total effects components to be 3.21 as follows:

Inversion	1. 09
Wind speed, 9 km/hr	1. 00
Temperature, 60° F. (15.5° C.)	. 12
Open terrain	. 30
No precipitation	. 70
	3. 21

(*c*) Using figure 13, place a hairline between 80 percent on the percent casualties scale and 12 hectares on the target area scale. On the point of intersection on the reference line, pivot the hairline until it intersects 3.21 on the effects components scale. On the munitions expenditure scale, read 12 as the number of 155-mm equivalents required.

(*d*) To find the number of 105-mm rounds required to fire the mission, multiply 12 by a factor of four (obtain this factor from figure 8); the product is 48 rounds.

(*e*) From figure 9, it is evident that one battery of six howitzers can easily fire the mission if no shift of fires is required. Since the target is twice as large as the dispersion pattern of a 105-mm battery (par. 31*c*(3)(*c*) and 41*d*), a shift of fires should be made. Figure 9 gives a time of 30 seconds for shifting of fires. On this basis the battery could fire twenty-four rounds on half the target in a little less than 30 seconds, take 30 seconds to shift fires, and have ample time to deliver the remaining twenty-four rounds on the other half of the target. The firing should be completed in less than 2 minutes.

Munition	Munition expressed in terms of 155-mm chemical equivalents		
	GB	VX	HD
155-mm Shell	1	1	1
105-mm Shell	0. 25	--------	0. 28
8-inch Shell	2. 40	2. 17	--------
4.2-inch Mortar Shell	--------	--------	. 62
175-mm Shell	2. 1	2. 1	--------
M55 Rocket	1. 6	1. 6	--------
M79 Warhead—HONEST JOHN	60	--------	--------
E19R2 Warhead—HONEST JOHN	71	71	--------
LITTLE JOHN	10	10	--------
SERGEANT	65	65	--------
M34A1 1000-lb Cluster	30	--------	--------
MC1 750-lb Bomb	35	--------	--------
5″/38 Gas Projectile (Navy)	. 50	--------	--------
5″/54 Gas Projectile (Navy)	. 68	--------	--------
5″ Gas Rocket (Navy)	. 74	--------	--------
500-lb Gas Bomb	17	--------	--------
115-lb Gas Bomb (Navy)	--------	--------	6. 2

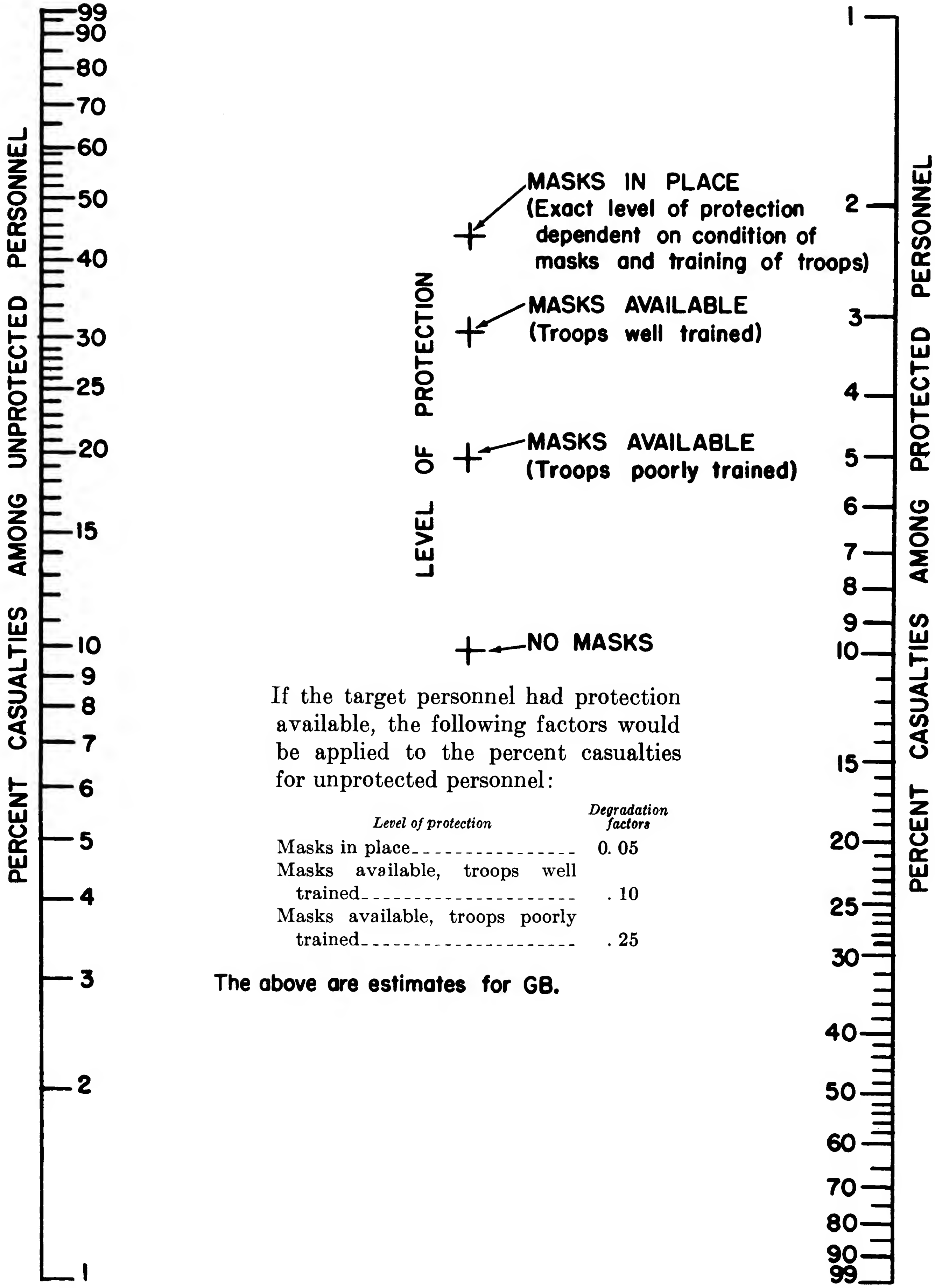
Figure 7. Munitions expressed in terms of 155-mm chemical equivalents. (The figures given are an estimate of the number of 155-mm howitzer rounds required to give the same effect as one round of the specified munition. Dissemination efficiency has not been considered.)

Munition	Conversion factor		
	GB	VX	HD
155-mm Shell	1	1	1
105-mm Shell	4	--------	3. 6
8-inch Shell	0. 41	0. 45	--------
4.2-inch Mortar Shell	--------	--------	1. 61
175-mm Shell	. 48	. 48	--------
M55 Rocket	. 61	. 61	--------
M79 Warhead—HONEST JOHN	. 017	--------	--------
E19R2 Warhead—HONEST JOHN	. 014	. 014	--------
LITTLE JOHN	. 098	. 098	--------
SERGEANT	. 016	. 016	--------
M34A1 1000-lb Cluster	. 033	--------	--------
MC1 750-lb Bomb	. 029	--------	--------
5″/38 Gas Projectile (Navy)	2. 00	--------	--------
5″/54 Gas Projectile (Navy)	1. 46	--------	--------
5″ Gas Rocket (Navy)	1. 35	--------	--------
500-lb Gas Bomb	. 059	--------	--------
115-lb Gas Bomb (Navy)	--------	--------	. 164

Figure 8. Conversion factors for converting 155-mm munitions to other munitions.

Weapon	Maximum rate (rounds)	Rates of fire for chemical fire missions without shifting or relaying of the piece (rounds)					Estimated time to shift fires
	30 sec	1 min	2 min	4 min	10 min	15 min	
105-mm Howitzer	6	10	14	18	40	60	30 sec
155-mm Howitzer	3	5	7	12	30	40	30 sec
155-mm Gun	2	4	6	8	12	18	60 sec
8-inch Howitzer	1	2	3	6	10	15	60 sec
4.2-inch Mortar	10	16	30 (max)	50	80	105	30 sec
M91 Launcher (M55 Rocket)	45 (15 sec)	Launcher must relocate after firing each ripple.					

Figure 9. Approximate rates of fire for division cannon artillery, mortars, and multiple rockets firing chemical rounds. (Rates of fire for other weapons are given in figure 5.)



If the target personnel had protection available, the following factors would be applied to the percent casualties for unprotected personnel:

Level of protection	*Degradation factors*
Masks in place	0. 05
Masks available, troops well trained	. 10
Masks available, troops poorly trained	. 25

The above are estimates for GB.

Figure 11. Nomogram for conversion of percent GB casualties for protection of personnel in the target area.

Meteorological and terrain conditions	Effects components			
	GB [2] (surprise attack)	GB (over 30-sec attack)	VX	HD
1. *Temperature Gradient*				
Inversion	0. 67	1. 09	1. 89	0. 69
Neutral	. 57	. 69	1. 89	. 54
Lapse	. 30	. 09	1. 89	. 32
2. *Wind Speed (km/hr)*				
0 to 5	. 20	1. 30	0	. 87
6 to 10	. 50	1. 00	0	. 70
11 to 16	. 70	. 70	0	. 60
17 to 26	. 55	. 30	0	. 48
27 to 52	. 30	0	0	0
3. *Temperature (° F.)*				
a. 0 to 39 (−18° to 4° C.)	0	0	0	----------
40 to 79 (5° to 26° C.)	. 12	. 12	0	----------
80 and up (27° C. and up)	. 23	. 23	0	----------
b. 30 to 49 (−1° to 9° C.)	----------	----------	0	0
50 to 69 (10° to 21° C.)	----------	----------	0	. 70
70 and up (22° C. and up)	----------	----------	0	1. 00
4. *Terrain*				
Open, level, scattered vegetation	. 30	. 30	0	. 30
Rugged, mountainous	0	[1] 0	[1] 0	[1] 0
5. *Precipitation*				
None	. 70	. 70	. 70	0
Moderate rain	0	[1] 0	[1] 0	[1] 0

[1] Estimated.
[2] Tentative figures not yet verified.

Figure 12. Effects components.

Note: paragraph 105 on page 82 states that the "safe entry times" after bio attacks are:

NU (Venezuelan equine encephalitis virus),
AB (bovine brucellosis), and
UL (tularemia): 2 hrs sun or 8 hrs cloudy
OU (Q fever): 2 hrs sun or 18 hrs cloudy

Cloudy conditions also apply to nighttime

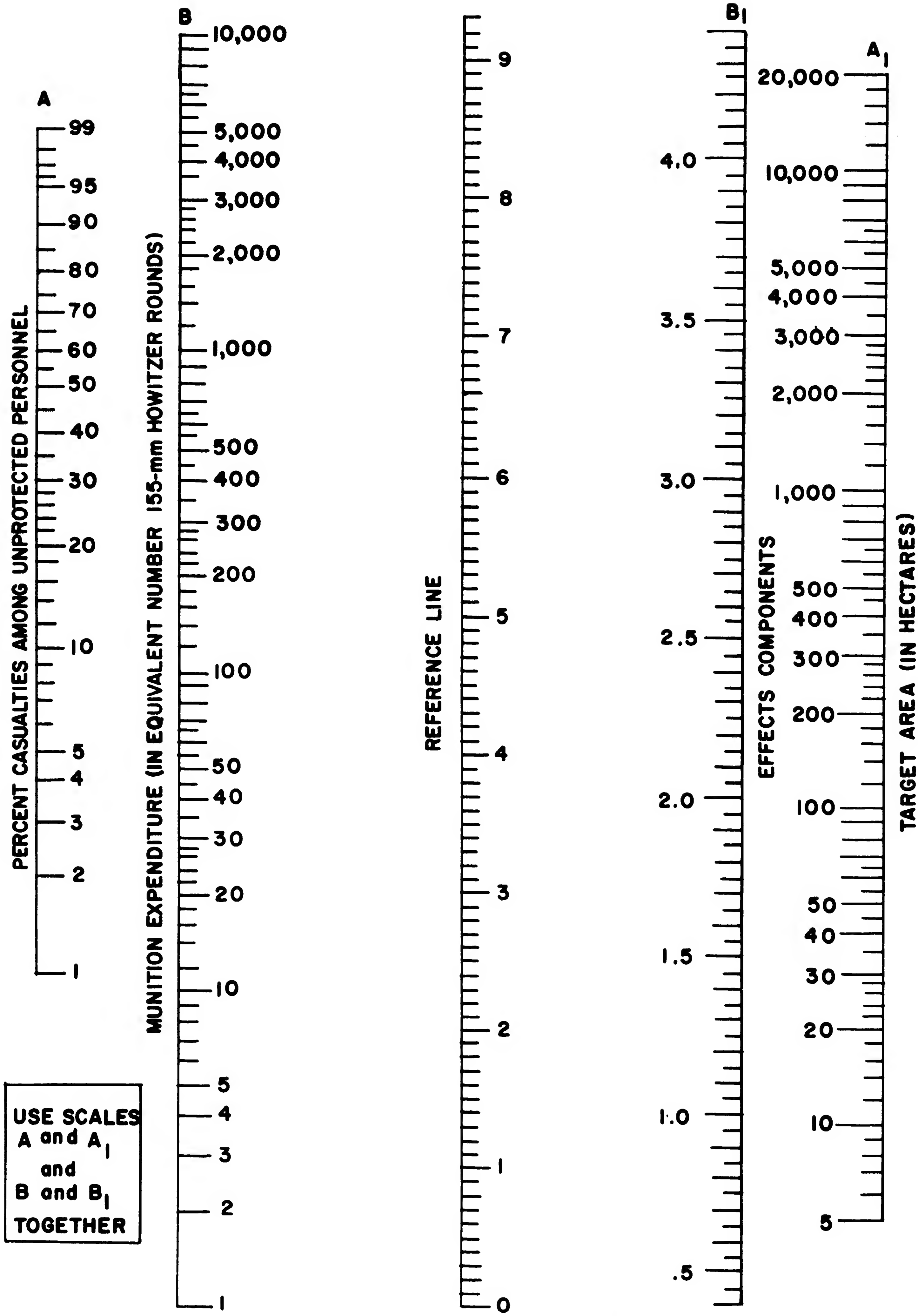


Figure 13. Target area, casualty level, munitions requirement nomogram.

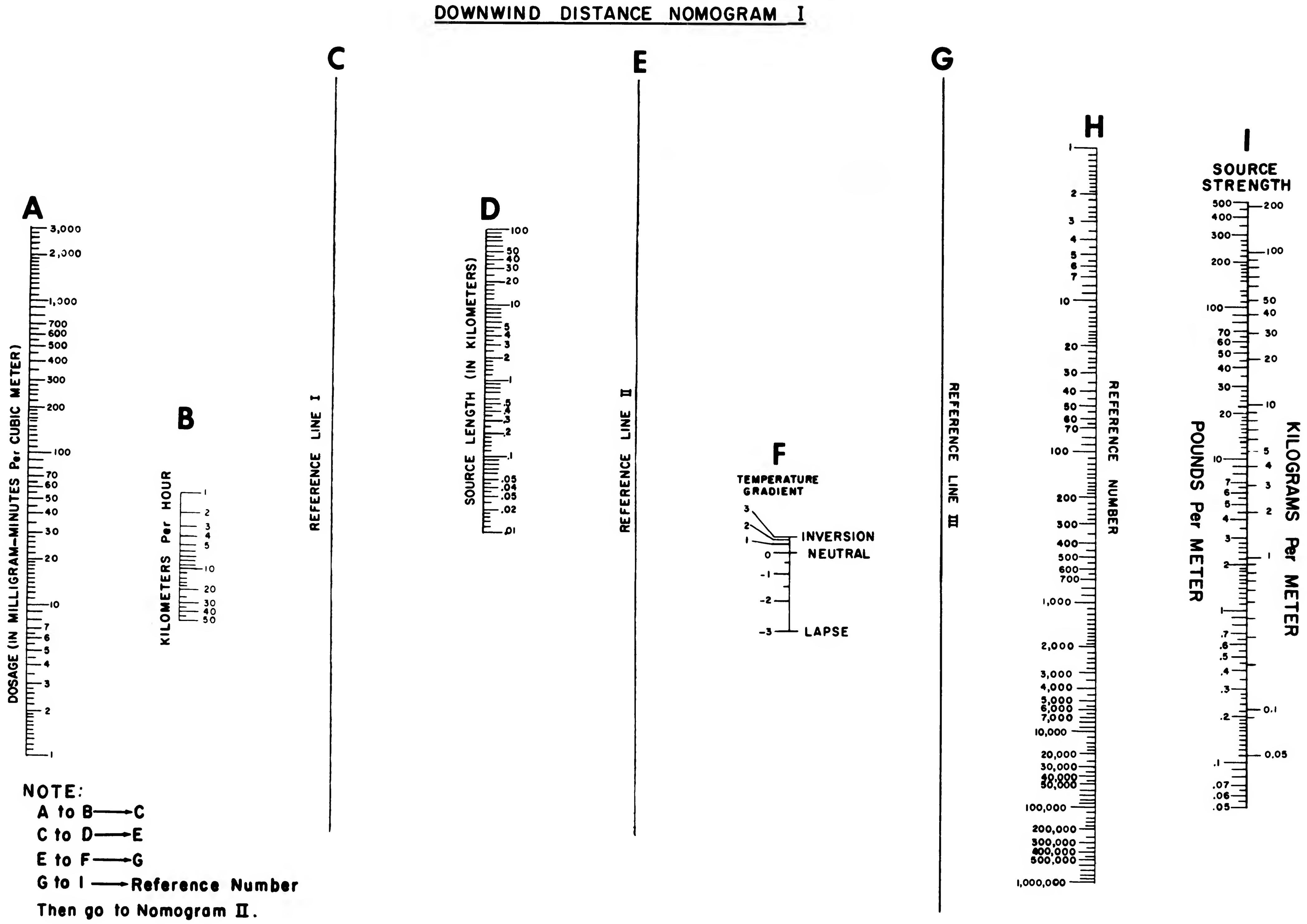


Figure 14. Downwind distance nomogram I.

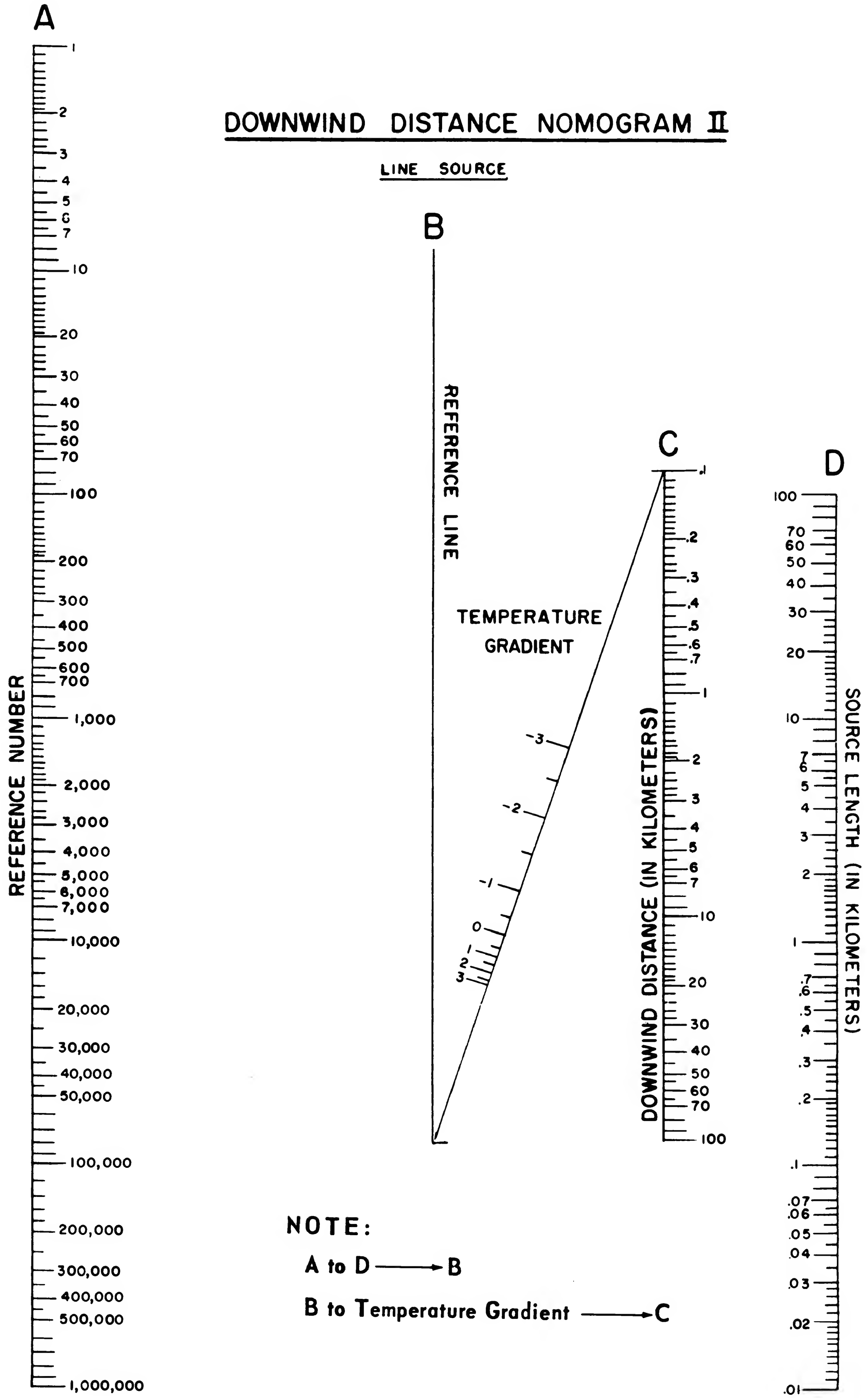


Figure 15. Downwind distance nomogram II.

USACGSC **RB 3-1**

REFERENCE BOOK

CHEMICAL AND BIOLOGICAL WEAPON EMPLOYMENT

U.S. ARMY COMMAND AND GENERAL STAFF COLLEGE
Fort Leavenworth, Kansas
1 May 1968

This reference book supersedes RB 3-1, 1 May 1967

CHAPTER 2
TOXIC CHEMICAL AGENTS

1. Characteristics and Effects

a. General. The following antipersonnel chemical agents are used for College instruction in chemical weapon employment: nerve agents GB and VX; blister agent HD (mustard); and incapacitating agent BZ. Actual or assumed characteristics of these agents are described in the following paragraphs for instructional purposes only and are summarized in figure 1.

b. Nerve Agent GB. GB is a quick acting, nonpersistent lethal agent that produces casualties primarily by inhalation.

(1) Inhalation effects. Inhaled GB vapor can produce casualties within minutes. As an example, 50 percent of a group of unprotected troops engaged in mild activity, breathing at the rate of about 15 liters per minute, and exposed to 70 milligrams of GB per cubic meter of air for 1 minute will probably die if they do not receive medical treatment in time. This is the median lethal dosage (50) and is expressed as 70 mg-min/m^3. For troops engaged in activities that increase their breathing rate, the median lethal dosage can be as low as 20 mg-min/m^3. The median incapacitating dosage of GB vapor by inhalation is about 35 mg-min/m^3 for troops engaged in mild activity. Incapacitating effects consist of nausea, vomiting, diarrhea, and difficulty with vision, followed by muscular twitching, convulsions, and partial paralysis. Dosages of GB less than the median incapacitating dosage cause general lowering of efficiency, slower reactions, mental confusion, irritability, severe headache, lack of coordination, and dimness of vision due to pinpointing of the eye pupils.

(2) Percutaneous effects. Percutaneous effects refer to those effects produced by the absorption of the agent through the skin. GB vapor absorbed through the skin can produce incapacitating effects. Sufficient GB liquid absorbed through the skin can produce incapacitation or death. The effectiveness of the liquid or vapor depends on the amount absorbed by the body. Absorption varies with the original amount of agent contamination, the skin area exposed and the exposure time, the amount and kind of clothing worn, and the rapidity in removing the contamination and/or contaminated clothing and in decontaminating affected areas of the skin.

(3) Major considerations in the employment of nerve agent GB. The employment of GB is based primarily on achieving casualties by inhalation of the nonpersistent vapor (or aerosol) of the agent. Major considerations in the employment of this agent are:

(a) Time to incapacitate. The onset of incapacitation resulting from inhalation of casualty-producing doses is rapid, the average time being approximately 3 minutes. To allow for the time required for the agent cloud to reach the individual, 10 minutes is used as the mean time to achieve incapacitation. Nonlethal casualties from GB will be incapacitated for 1 to 5 days.

(b) Persistency. Persistency is defined as the length of time an agent remains effective in the target area after dissemination. Nerve agent GB is considered nonpersistent. GB clouds capable of producing significant casualties will dissipate within minutes after dissemination. Some liquid GB will remain in chemical shell or bomb craters for periods of time varying from hours to days, depending on the weather conditions and type of munition. Because of this continuing but not readily discernible threat, GB can also be highly effective in harassing roles by causing exposure to low concentrations of the vapor. Rounds fired sporadically may compel the enemy to wear protective masks and clothing for prolonged periods, thereby impairing his effectiveness as a result of fatigue, heat stress, discomfort, and decrease in perception.

(c) Level of protection. The weapon system requirements for positive neutralization of masked personnel by GB are too great to be supported except for important point or small area targets. A major factor affecting casualties resulting from GB attacks of personnel equipped with masks but unmasked at the time of attack is the time required for enemy troops to mask after first detecting a chemical attack. Therefore, surprise dosage attack is used to establish a dosage sufficient to produce the desired casualties before troops can mask. Casualty levels for surprise dosage attack that are tabulated in the weapon system effects tables (app A) are based on an assumed enemy masking time of 30 seconds. (Refer to FM 3-10 series manuals for operational data for masking times less than 30 seconds.) A total dosage attack is used to build up the dosage over an extended period of time and is normally employed against troops who have no protective masks available. Dosages built up before troops can mask inside foxholes, bunkers, tanks, buildings, and similar structures will generally be less than dosages attained during the same period of time in the open, thereby reducing the effects on occupants from surprise dosage attacks. Total dosage effects are essentially the same inside or outside.

c. Nerve Agent VX. VX is a slow-acting, lethal, persistent agent that produces casualties primarily by absorption of droplets through the skin.

(1) Effects. VX acts on the nerve systems of man; interferes with breathing; and causes convulsions, paralysis, and death.

(2) Major considerations in the employment of nerve agent VX.

(a) General. Agent VX disseminated in droplet (liquid) form provides maximum duration of effectiveness as a lethal casualty threat. VX will remain effective in the target area for several days to a week depending on weather conditions. Because of its low volatility, there is no significant vapor hazard downwind of a contaminated area. Except when disseminated by aircraft spray tanks, meteorological conditions have little effect on the employment of VX, although strong winds may influence the distribution of the agent and heavy rainfall may wash it away or dissipate it.

(b) Employment to cause casualties. Agent VX is appropriate for direct attack of area targets containing masked personnel in the open or in foxholes without overhead protection, for causing severe harassment by the continuing casualty threat of agent droplets on the ground or on equipment, and for creating obstacles to traversing or occupying areas. Casualties produced by agent VX are delayed, occurring at times greater than 1 hour after exposure. Although this agent can be used relatively close to friendly forces, it should not be used on positions that are likely to be occupied by friendly forces within a few days. Because of this continuing hazard, areas in which agent VX has been used should be recorded in a manner similar to minefields or fallout areas so that necessary precautions can be taken.

d. Blister Agent HD. HD, sometimes referred to as mustard, is a persistent slow-acting agent that produces casualties through both its vapor and liquid effects.

(1) Vapor effects.

(a) The initial disabling effect of HD vapor on unmasked troops will be injuries to the eyes. Temporary blindness can be caused by vapor dosages that are insufficient to produce respiratory damage or skin burns. However, skin burns account for most injuries to masked troops. The vapor dosages and the time required to produce casualties (4 to 24 hours) vary with the atmospheric conditions of temperature and humidity and with the amount of moisture on the skin. Depending on their severity, skin burns can limit or entirely prevent movement of the limbs or of the entire body.

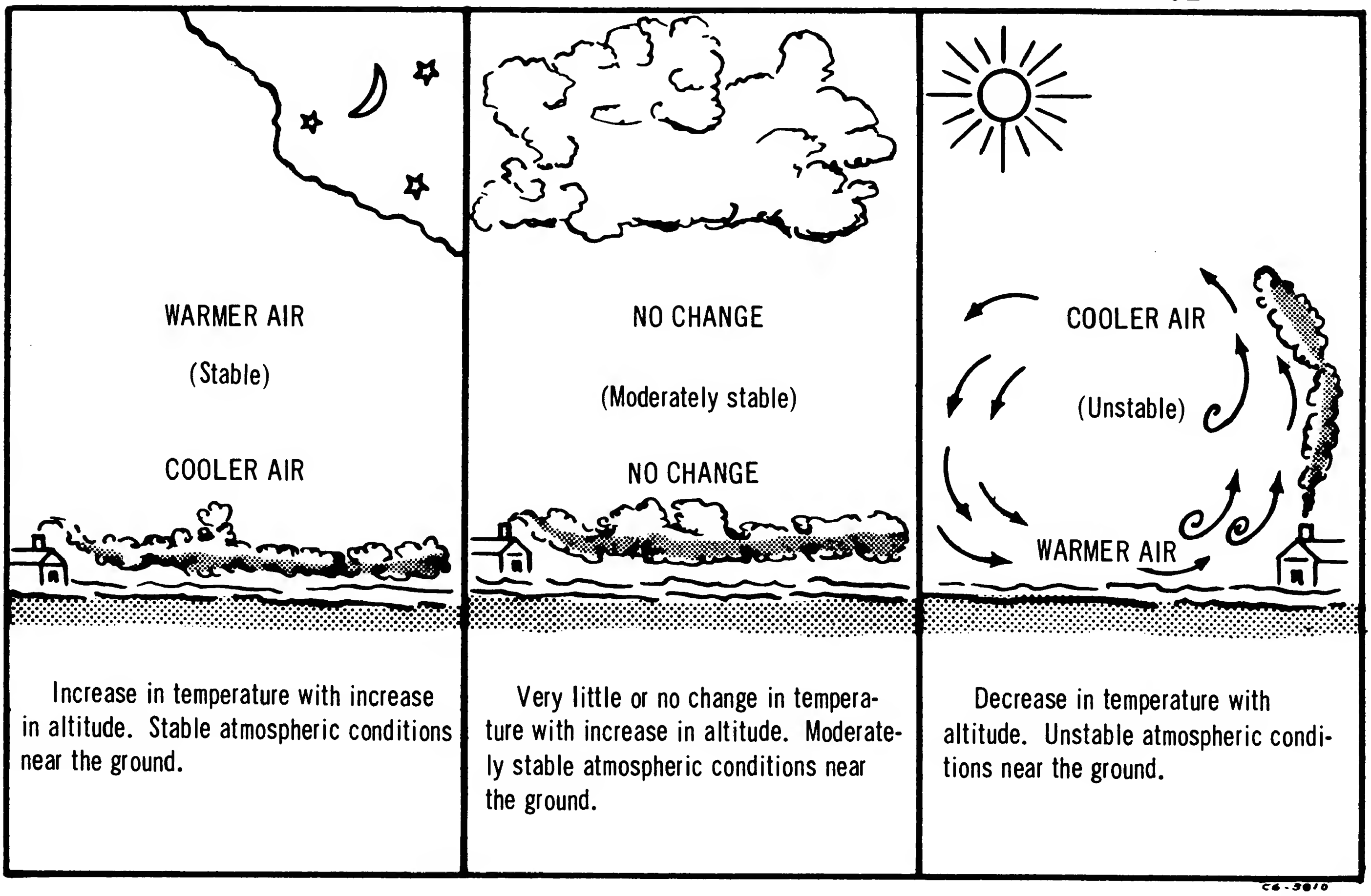


Figure 2. Temperature gradients.

Surprise dosage GB attacks are influenced only slightly by the temperature gradient except when made with the spray tank. Downwind vapor hazards to both enemy and friendly forces will be most significant during inversion and neutral conditions. Employment of VX is not affected by the temperature gradient.

Temperature gradients	Time
1. Inversion	From sunset to sunrise.
2. Neutral	2 hours before sunset to sunset, sunrise to 2 hours after sunrise, or any time windspeed is 15 kmph or greater.
3. Lapse	2 hours after sunrise to 2 hours before sunset.

Figure 3. Estimated times that temperature gradients will prevail. (Use when meteorological data are not available.)

(3) When actual or predicted meteorological conditions are not available for a target analysis, 70° F is used for temperature, 9 kmph is used as windspeed, and the temperature gradient is approximated from figure 3.

d. Windspeed and Direction.

(1) Air moving over the earth's surface sets up eddies, or mechanical turbulences, that act to dissipate a chemical cloud. A condition of calm will limit the merging of the individual gas clouds. Both of these conditions may reduce the effectiveness of a chemical agent attack. High winds increase the rate of evaporation of HD and dissipate chemical clouds more rapidly than low winds. Moderate winds are desirable for chemical employment. Large-area nonpersistent chemical attacks are most effective in winds not exceeding 28 kmph. Small-area nonpersistent chemical attacks with rockets or shell are most effective in winds not exceeding 9 kmph. However, if the concentration of chemical agent can be established quickly, the effects of high windspeed can be partially offset.

CHAPTER 4

EMPLOYMENT OF BIOLOGICAL AGENTS

1. General

a. Antipersonnel biological agents are micro-organisms that produce disease in man. These agents can be used to incapacitate or kill enemy troops through disease. They may cause large numbers of casualties over vast areas and could require the enemy to use many personnel and great quantities of supplies and equipment to treat and handle the casualties. Many square kilometers can be effectively covered from a single aircraft or missile. The search capability of biological agent clouds and the relatively small dose required to cause infection among troops give biological munitions the capability of covering large areas where targets are not precisely located.

b. A biological attack can occur without warning since biological agents can be disseminated by relatively unobtrusive weapon systems functioning at a considerable distance from the target area and relying upon air movement to carry the agent to the target.

c. Biological agents do not produce effects immediately. An incubation period is required from the time the agent enters the body until it produces disease. Some agents produce the desired casualty levels within a few days, whereas others may require more time to produce useful casualty levels. A variety of effects may be produced, varying from incapacitation with few deaths to a high percentage of deaths, depending on the type of agent.

2. Methods of Dissemination

a. The basic method of disseminating antipersonnel biological agents is the generation of aerosols by explosive bomblets and spray devices. Because exposure to sunlight increases the rate at which most biological agent aerosols die and thereby reduces their area coverage, night is the preferable time for most biological attacks. However, if troop safety is a problem, an attack may be made near sunrise to reduce the distance downwind that a hazard to friendly forces will extend. Conversely, to extend the downwind cloud travel and the area coverage from spray attack, a biological agent may be employed soon after sundown.

b. Missile-delivered Biological Munitions. Missile-delivered biological munitions are used for attack of large-area targets. A typical biological missile system consists of the following components:

(1) A missile vehicle and its launching equipment.

(2) A warhead that can be opened at a predetermined height to release biological bomblets over the target area. The warhead is shipped separately for assembly to a missile at the launching site.

(3) A warhead shipping container equipped with a heating-cooling element and a temperature control unit.

(4) Biological bomblets consisting of an agent container and a central burster that functions on impact. The bomblets have vanes that cause them to rotate in flight, thereby achieving lateral dispersion during their free fall and resulting in random distribution as a circular pattern.

c. Aircraft Spray Tank. Biological agents released from an aircraft spray tank cover a large area downwind of the line of release. A typical spray tank consists of the following components:

(1) An agent reservoir section that is shipped separately in an insulated shipping and storage container equipped with a heating-cooling element and a temperature control unit.

(2) A discharge nozzle assembly that can be mechanically adjusted to vary the agent flow rate.

Table 1. Chemical Weapons Data

1	2	3	4	5	6	7	8	9	10	11	12	13
Delivery system	Range (meters)		Agent	Munition	No of weapons per delivery unit	Weapon rate of fire	RT max (meters)[1 2]					Reference (table)
							Fire unit	Total dosage		Surprise dosage		
								Casualty threat		Casualty threat		
	Min	Max						10%	30%	10%	30%	
4.2-in mortar	180	4,500	HD	Cartridge, M2A1	4/Plat	50 rd/3 min 105 rd/15 min						18 19
105-mm howitzer		11,100	GB	Cartridge, M360	6/btry	5 rd/30 sec 30 rd/3 min 66 rd/15 min	1 btry[3]	200	100	100	50	2
							1 bn[3]	300	300	200	100	3
			HD	Cartridge, M60								18 19
155-mm howitzer		14,600	GB	Projectile, M121	6/btry	2 rd/30 sec 12 rd/3 min 24 rd/15 min	1 btry[3]	300	200	100	0	4
							1 bn[3]	500	400	300	100	5
			HD	Projectile, M110								18 19
			VX[4]	Projectile, M121			1 btry[3]	400	200	NA	NA	13
							1 bn[3]	500	400			
8-in howitzer		16,800	GB	Projectile, M426	4/btry	1 rd/30 sec 4 rd/3 min 10 rd/15 min	1 btry[3]	300	200	200	0	6
							1 bn[3]	500	400	300	100	7
			VX[4]				1 btry[3]	400	200	NA	NA	14
							1 bn[3]	500	400			
115-mm multiple rocket launcher, M91	2,740	10,600	GB[4]	Rocket, M55 (THE BOLT)		45 rkt/lchr/15 sec	1 lchr	1,000	750	500	200	8
							3 lchr	1,000	1,000	750	400	
							6 lchr	1,000	1,000	1,000	750	
							9 lchr	1,000	1,000	1,000	1,000	
			VX[4]				1 lchr	300	0	NA	NA	15
							3 lchr	750	300			
							6 lchr	1,000	400			
							9 lchr	1,000	750			
762-mm rocket, Honest John	8,500	38,000	GB[4]	Warhead, M190 (M139 bomblets)	2/btry	2 rkt/lchr/hr	1 lchr	600	600	600	400	9
							2 lchr	600	600	600	400	
Sergeant missile	46,000	139,000	GB[4]	Warhead, M212 (M139 bomblets)	2/bn	2 msl/lchr/hr	1 msl	600	400	600	200	10
							2 msl	600	600	600	400	
Aircraft	Dependent on type aircraft		GB[4]	Bomb, MC-1, 750-lb		Dependent on type aircraft	1 bomb	50				11
							6 bombs	300	200	300	50	
							12 bombs	500	300	400	200	
							24 bombs	500	300	500	300	
			GB[4]	Spray tank, 100-gal			1 spray tank 2 spray tanks	RT max=750 meters (one-half effective spray release line length)				12
			VX[4]				1 spray tank	RT max=500 meters (one-half effective spray release line length)				16
			BZ[4]	Bomb, 150-lb Bomb, 700-lb								17

[1]RT max is largest target radius for which indicated casualty threat is tabulated for appropriate fire unit. Division of target into subtargets NOT considered.

[2]All windspeeds, temperature gradients, and protection categories considered.

[3]RT max computed for maximum number of volleys for which data are tabulated.

[4]Weapon system capabilities derived from tables composed of hypothetical data for INSTRUCTIONAL PURPOSES ONLY at the U. S. Army Command and General Staff College. For actual data, refer to FM 3-10.

Table 2. Estimated Fractional Casualty Threat From 105-mm Howitzer, GB Projectile, Battery Fire[1 2]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Target radius–radius of effect (meters)	Range to target (km)	No of volleys	Windspeed[3]											
			4 kmph				9 kmph				28 kmph			
			Surprise[4]	Total dose[5]			Surprise[4]	Total dose[5]			Surprise[4]	Total dose[5]		
				I	N	L		I	N	L		I	N	L
50	<7.5	1	.10	.25	.20	.15	.10	.15	.10	.10				
		2	.20	.45	.40	.30	.15	.30	.25	.20		.10	.05	.05
		3	.30	.60	.60	.35	.30	.50	.45	.30	.10	.20	.15	.10
		4	.30	.75	.70	.45	.30	.55	.45	.35	.10	.25	.20	.10
		5	.35	.90	.85	.55	.35	.60	.50	.40	.15	.30	.25	.15
	>7.5	1	.05	.15	.15	.10	.05	.10	.05	.05				
		2	.15	.30	.25	.15	.10	.20	.15	.10		.05	.05	
		3	.15	.30	.30	.25	.10	.20	.20	.15		.10	.05	.05
		4	.20	.40	.35	.25	.15	.30	.30	.15	.05	.15	.15	.05
		5	.25	.45	.45	.30	.25	.40	.35	.25	.10	.20	.20	.10
100	<7.5	1	.05	.15	.15	.10	.05	.10	.05	.05				
		2	.10	.30	.30	.15	.10	.20	.15	.10				
		3	.15	.40	.35	.20	.15	.25	.25	.15	.05	.10	.05	
		4	.15	.40	.35	.30	.15	.30	.30	.15	.05	.10	.10	.05
		5	.20	.45	.40	.35	.20	.35	.35	.20	.10	.15	.15	.10
	≥7.5	1	.05	.10	.10	.05		.05	.05					
		2	.10	.20	.20	.10	.05	.15	.10	.05				
		3	.10	.25	.25	.15	.10	.15	.15	.10		.05	.05	
		4	.10	.30	.25	.20	.10	.25	.20	.15		.10	.05	
		5	.15	.35	.30	.25	.15	.30	.25	.15	.05	.15	.10	.05
200	Any	1		.05	.05									
		2		.10	.10	.05		.05	.05					
		3	.05	.15	.15	.05		.10	.05					
		4	.05	.15	.15	.10		.10	.10					
		5	.05	.20	.20	.10	.05	.15	.10	.05				

[1]Blank spaces indicate fractional casualties are below 0.05.

[2]If the target is predominately wooded, use a windspeed of 4 kmph and neutral temperature gradient for total dose attack; use a windspeed of 4 kmph for surprise attack.

[3]For windspeeds other than those shown, use data given for the nearest windspeed.

[4]Multiply the figures given in the table by the appropriate factor to obtain the fractional casualties from surprise dose attack:

Troops in open foxholes:	0.7
Troops in covered foxholes or bunkers:	0.6

[5]I=inversion, N=neutral, L=lapse.

Table 17. BZ Munitions Requirements

1	2	3	4	5	6
Munition	Casualty level[2]	Area coverage[1] (square kilometers)			
		Windspeed[3]			
		8 kmph		16 kmph	
		Temperature gradient		Temperature gradient	
		Inversion	Neutral	Inversion	Neutral
150-lb bomb	.40	.05	.02	.03	.01
	.75	.03	.01	.02	.009
700-lb bomb	.40	.20	.07	.09	.04
	.75	.10	.04	.05	.03

[1]Area coverages are for one bomb.

[2]Casualty levels are for personnel without masks available. For personnel with masks available, multiply casualty levels by 0.7.

[3]For windspeeds other than those shown, use data given for the nearest windspeed.

NOTE: The above table is composed of hypothetical munitions and data for INSTRUCTIONAL PURPOSES ONLY at the U. S. Army Command and General Staff College. For actual data, refer to FM 3-10.

Table 18. HD Ammunition Expenditure for Vapor Effect (50 Percent Coverage of Target Area)[1 2]

Desired effect[3]	Rounds required per hectare																																							
	Exposure time (hours)				4.2-inch mortar (cartridge M2A1)												105-mm howitzer (cartridge M60)												155-mm howitzer and gun (projectiles M110 and M104)											
					Windspeed (kmph)												Windspeed (kmph)												Windspeed (kmph)											
	Temperature (°F)				6			9			15			26			6			9			15			26			6			9			15			26		
					Temperature gradient[4]												Temperature gradient[4]												Temperature gradient[4]											
	55°	70°	85°	100°	I	N	L	I	N	L	I	N	L	I	N	L	I	N	L	I	N	L	I	N	L	I	N	L	I	N	L	I	N	L	I	N	L	I	N	L
Cause eye irritation to troops without masks.	1	½	¼	⅛	10	14	16	11	21	22	15	22	26	20	24	29	22	24	27	24	34	39	39	44	46	32	53	65	8	10	10	9	11	12	10	12	13	11	14	16
	2	1	½	¼	6	8	9	8	12	14	12	13	16	17	21	24	18	22	23	20	22	27	29	32	34	26	39	51	6	8	9	8	10	11	9	11	12	10	12	14
	4	2	1	½	6	6	8	8	9	10	9	10	13	13	16	20	16	17	20	17	18	20	20	22	24	22	29	39	4	5	6	6	8	9	8	9	10	9	10	12
	8	4	2	1	4	6	6	6	8	9	8	9	11	12	13	15	12	15	17	13	12	17	15	20	22	18	27	36	4	5	5	5	6	8	6	8	9	8	9	11
	16	8	4	2	4	5	5	5	8	9	8	8	10	10	11	13	10	12	13	10	11	15	12	17	20	15	24	34	4	4	4	4	5	6	5	6	8	5	8	10
Disable masked troops (sweating in humid weather).	1	½	¼	⅛	35	46	52	39	53	63	46	63	80	59	77	108	70	83	108	77	95	121	95	123	166	108	157	243	20	28	30	23	32	36	26	39	44	32	46	58
	2	1	½	¼	20	29	33	24	35	40	30	45	56	41	59	69	42	54	63	47	63	84	66	89	102	82	108	192	12	17	20	15	22	24	18	27	34	24	36	46
	4	2	1	½	15	21	24	17	27	33	24	35	42	30	47	65	27	36	45	32	47	62	48	64	84	64	88	162	10	13	16	11	18	20	15	20	27	18	29	33
	8	4	2	1	11	17	18	13	21	26	17	28	38	27	45	63	18	29	34	24	38	47	33	53	76	54	83	138	6	10	12	9	13	16	12	17	24	16	23	33
	16	8	4	2	9	14	16	11	18	22	16	24	33	24	42	58	15	23	27	18	32	42	30	51	66	48	72	120	5	9	11	8	11	15	11	15	22	15	20	29
Disable masked troops (dry weather).	1	½	¼	⅛	64	83	95	72	95	114	86	113	144	108	144	198	128	154	174	144	174	212	189	...	...	202	...	...	36	48	53	41	56	63	46	66	78	59	83	105
	2	1	½	¼	36	52	58	44	62	72	57	81	101	71	120	125	75	98	128	89	113	147	111	156	180	148	198	288	21	28	33	26	36	41	38	54	63	42	65	84
	4	2	1	½	26	35	41	30	46	56	45	62	76	57	86	119	50	64	81	59	86	111	88	118	153	117	165	256	15	21	26	18	28	33	26	36	45	33	50	66
	8	4	2	1	18	27	30	23	35	44	32	50	68	50	81	114	33	50	58	45	65	84	62	95	138	101	154	240	11	16	18	13	21	26	22	33	40	28	42	56
	16	8	4	2	13	21	26	18	30	40	29	46	60	42	72	108	26	39	45	34	56	72	54	84	120	84	132	193	9	12	15	11	18	21	18	30	36	24	38	46

[1]For open terrain. For heavily wooded terrain or jungle, multiply the figure obtained by 0.5 to obtain the appropriate expenditure.

[2]Blank spaces indicate excessive expenditures.

[3]An average of 50 percent casualties is expected among all troops who remain in the target area for the times specified.

[4]I=inversion, N=neutral, L=lapse.

[redacted]

S/C

DEPARTMENT OF THE ARMY FIELD MANUAL	FM 3–10B
NAVAL WARFARE INFORMATION PUBLICATION	NWIP 36–4
DEPARTMENT OF THE AIR FORCE MANUAL	AFM 355–9
MARINE CORPS MANUAL	FMFM 11–3B

EMPLOYMENT OF CHEMICAL AGENTS (U)

This copy is a reprint which includes current pages from Changes 1.

[redacted]

[redacted]

DEPARTMENTS OF THE ARMY, THE NAVY AND THE AIR FORCE

NOVEMBER 1966

[redacted]

CHAPTER 1
INTRODUCTION

Section I. GENERAL

1. (U) Purpose

This manual provides classified data on chemical agents and on the capabilities and effects of chemical munitions. When used in conjunction with its unclassified counterpart, FM 3-10/NWIP 36-2/AFM 355-4/FMFM 11-3, Employment of Chemical and Biological Agents, it provides guidance in planning the employment of chemical munitions.

2. (U) Scope

This manual contains classified data on lethal agents VX and GB and incapacitating agent BZ; munitions effects tables; and predicted effects of ground-fired and air-released munitions utilized to disseminate these agents. As a joint publication, it discusses all appropriate chemical munitions of the U.S. Army, Navy, Air Force, and Marine Corps. Unclassified HD chemical munitions expenditure tables and guidance in chemical target analysis and casualty estimation are given in FM 3-10/NWIP 36-2/AFM 355-4/FMFM 11-3.

3. (U) Reliability

Data contained in this manual are based on proving ground tests and field tests, analytical studies of such data, and predictions extrapolated from mathematical models.

4. (U) Army, Navy, Air Force, and Marine Corps User Comments

Users of this manual are encouraged to submit recommended changes or comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons for each comment should be provided to insure understanding and complete evaluation. Comments should be forwarded direct to the Commanding Officer, U.S. Army Combat Developments Command CBR Agency, Fort McClellan, Ala. 36205, with an information copy to the cognizant service doctrinal development agency.

Section II. ANTIPERSONNEL CHEMICAL AGENTS

6. ~~(C)~~ (U) Incapacitating Agent BZ

This agent is disseminated as an aerosol to produce physical and mental effects when inhaled. The effects are temporary, and recovery is normally complete. There may be permanent ill effects in a few instances among the very young, the aged, and the infirm, or when massive dosages are received.

a. Tactical Employment. BZ is employed against carefully selected targets to incapacitate enemy troops when the use of lethal or destructive munitions is undesirable. This agent may be particularly useful in situations where adequate protective equipment is normally not available to enemy troops or where the status of training or mask discipline is poor, such as in counter-insurgency operations.

b. Limitations. BZ has the following limitations:

(1) The white agent cloud produced by pyrotechnic mixtures acts as a visible alarm.

(2) BZ may be defeated by improvised respiratory protection such as a folded cloth over mouth and nose.

(3) The effects are not immediate but require an average onset time of about 3 to 6 hours.

(4) There is no known antidote to treat affected friendly personnel.

c. Median Incapacitating Dosage (ICt_{50}). This is about 110 mg-min/m³ for man engaged in mild activity (breathing rate of 15 liters/min).

d. Physiological and Psychological Symptoms. The symptoms listed below will become more intense as the dosage received increases. They also vary according to the inherent characteristics of each individual exposed to the agent. Because of the many variables involved, estimation of the percentage and type of casualties produced from a BZ attack is difficult. Approximations for the occurrence of ultimate casualties among unmasked personnel are 5 percent in 2 hours, 50 percent in 4½ hours, and 95 percent in 9½ hours.

(1) Symptoms likely to appear in 30 minutes to 3 hours: dizziness, extreme drowsiness, dryness of the mouth, and increased heartbeat.

(2) Symptoms likely to appear in 3 to 5 hours: restlessness, involuntary muscular movement, near vision impairment, and physical incapacitation.

(3) Symptoms likely to appear in 6 to 10 hours: hallucinations, lack of muscular coordination, disorientation, and difficulty in memory recall.

e. Duration of Incapacitation. The duration of incapacitation varies with the dosage received—from 24 hours to 5 days.

f. Duration of Effectiveness. Under average meteorological conditions in the open, the aerosol is normally effective for only a few minutes after dissemination, since the fine BZ particles travel

[redacted]

27. (U) CBU-5B/M43 750-Pound BZ Cluster Bomb

Both the U.S. Air Force CBU-5B and the U.S. Army M43 750-pound cluster bombs contain 57 M138 BZ-filled bomblets. The U.S. Army M43 cluster is designed for delivery by aircraft at low speeds. When modified and equipped with a suitable fairing for streamlining purposes, an internal arming wire system, and a strengthened tail fin, it is then designated the CBU-5B and can be delivered by high-performance aircraft.

a. Operational Concepts. The BZ cluster bomb is used on carefully selected targets against enemy personnel when the use of lethal chemical or destructive weapon systems is militarily or politically undesirable. See paragraph 6 for additional data.

b. Characteristics. The cluster contains about 85 pounds of agent BZ and employs two tail mechanical time fuzes. To function properly, the cluster must be released above 6,200 feet so as to allow the cluster to open at approximately 4,500 feet. The M138 bomblet contains four canisters, each with three-fourth pound of agent-pyrotechnic mixture (50/50 ratio), and an "all-ways" impact fuze. The bomblet is *not* self-dispersing.

c. Capabilities. The cluster delivers M138 bomblets over an elliptical impact area having a cross section of approximately 100 by 200 meters when released at heights above 6,200 feet. One cluster can cover about 12,000 square meters (1.2 hectares) with an incapacitating total dosage of BZ (110 mg-min/m^3) under neutral temperature gradient and in a wind speed between 2 and 10 knots; under lapse temperature gradient conditions, the area coverage will be smaller. Under optimum delivery conditions, the area coverage for one cluster is expected to range from 15,000 to 20,000 square meters. Field tests indicate that wind speed has only minor effects upon area coverage.

d. Operational Considerations. Refer to the appropriate technical order/flight manual to determine aircraft loads (see para 16*d*).

[redacted]

Field Manual
No 3-6

Air Force Manual
No 105-7

Fleet Marine Force Manual
No. 7-11-H

HEADQUARTERS
DEPARTMENT OF THE ARMY
DEPARTMENT OF THE AIR FORCE
UNITED STATES MARINE CORPS
Washington, DC, 3 November 1986

FIELD BEHAVIOR OF NBC AGENTS (INCLUDING SMOKE AND INCENDIARIES)

Table of Contents

DISPERSION CATEGORY	ATMOSPHERIC DESCRIPTION	TRADITIONAL ATMOSPHERIC CONDITIONS
1	Very Unstable	Lapse
2	Unstable	Lapse
3	Slightly Unstable	Neutral
4	Neutral	Neutral
5	Slightly Stable	Neutral
6	Stable	Inversion
7	Extremely Stable	Inversion

Figure 1-1. Atmospheric stability categories and conditions.

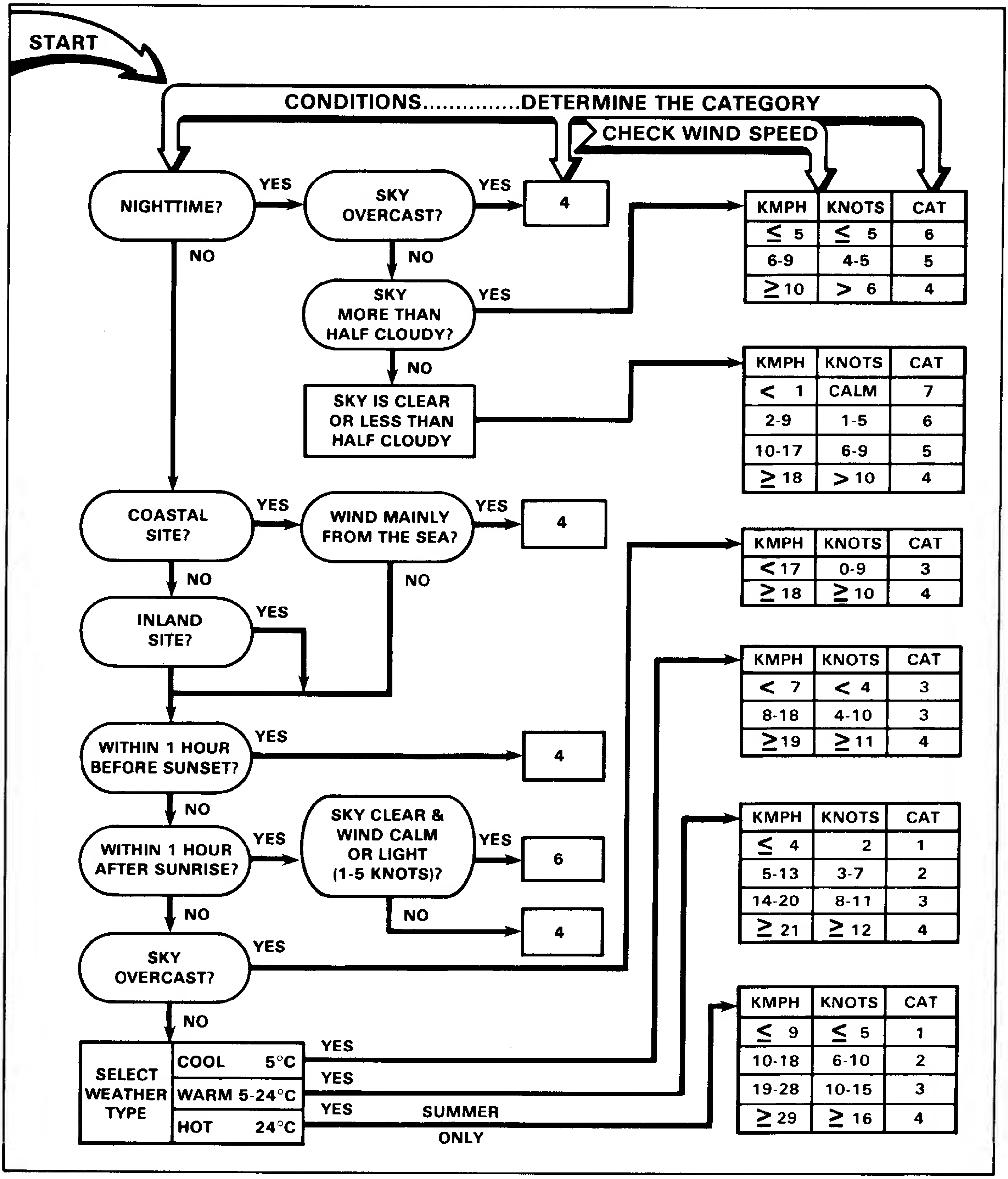


Figure 1-2. Stability decision tree.

Page 1-14 states that the mixed air layer height is 50-100 m on a clear, calm night, 400 m just before sunrise, and 2 km on a hot summer day

Table 1-3. Center line dosages at different distances downwind for different dispersion categories and wind speeds for a unit source. 100 kilograms of GB

Stability Category	Wind Speed	Downwind distance in km: .5	1	2	4	6	10	20	30
		Dosages (mg-min/M³)							
1	1	57.82	10.960	2.4820	1.2070	.8048	.48290	.24140	.16100
	3	19.15	3.628	.8224	.3998	.2665	.15990	.07995	.05330
	5	11.47	2.174	.4928	.2396	.1597	.09582	.04791	.03194
2	3	65.93	16.480	4.121	1.0300	.4671	.22840	.11360	.07575
	6	32.86	8.215	2.054	.5135	.2328	.11380	.05663	.03775
	10	19.75	4.938	1.235	.3087	.1400	.06843	.03404	.02269
3	3	172.60	46.26	12.400	3.321	1.5370	.5825	.18010	.11510
	7	73.86	19.79	5.302	1.421	.6576	.2492	.07703	.04925
	12	43.09	11.55	3.094	.829	.3837	.1454	.04494	.02874
4	3	572.4	170.20	50.590	15.040	7.398	3.0260	.8997	.44450
	8	213.9	63.61	18.910	5.622	2.765	1.1310	.3363	.16620
	16	107.1	31.84	9.467	2.814	1.384	.5662	.1683	.08318
5	2	1,837.0	606.0	199.90	65.94	34.470	15.220	5.021	2.6250
	5	736.2	242.9	80.12	26.43	13.810	6.101	2.012	1.0520
	9	408.7	134.8	44.47	14.67	7.668	3.387	1.117	.5839
6	1	10,080.0	3,691.0	1,351.0	494.50	274.70	131.00	47.930	26.630
	3	3,339.0	1,222.0	447.4	163.80	90.96	43.37	15.870	8.818
	5	2,001.0	732.4	268.1	98.12	54.51	25.99	9.5120	5.284
7	HIGHER DOSAGES THAN ABOVE								

Table 1-4. Summary of favorable and unfavorable weather and terrain conditions for tactical employment of chemical agent vapor or aerosol. (The stability condition listed for the south slope is for the northern hemisphere; due to solar loading on the slope, the situation would be reversed for the southern hemisphere.)

FACTOR	UNFAVORABLE	MODERATELY FAVORABLE	FAVORABLE
Wind	Artillery employment if speed is more than 7 knots. Aerial bombs if speed is more than 10 knots.	Steady, 5 to 7 knots, or land breeze.	Steady, less than 5 knots, or sea breeze.
Dispersion Category	Unstable (lapse).	Neutral.	(Stable) inversion.
Temperature	Less than 4.4°C.	4.4° to 21.1°C.	More than 21.1°C.
Precipitation	Any.	Transitional.	None.
Cloud Cover	Broken, low clouds during daytime. Broken, middle clouds during daytime. Overcast or broken, high clouds during daytime. Scattered clouds of all types during daytime. Clouds of vertical development.	Thick, low overcast. Thick, middle overcast.	Broken, low clouds at night. Broken, middle clouds at night. Overcast or broken, high clouds at night. Scattered clouds of all types at night. Clear sky at night.
Terrain	Hilltops, mountain crests. South slopes* during daytime.	Gently rolling terrain. North slopes at night.	Even terrain or open water.
Vegetation*	Heavily wooded or jungle.	Medium dense.	Sparse or none.

*Cloud dissemination occurs above the canopy.

Chemical and biological contamination avoidance, FM 3-3 (1992)

10 grams/square meter

TABLE 1-2. Chemical Agent Persistency in Hours on CARC Painted Surfaces.

Temperature		GA/ GF[1]	GB[2,3]	GD[2,3]	HD[1]	VX[2,3]
C°	F°					
-30	-22	*	110.34	436.69	**	***
-20	-4	*	45.26	145.63	**	***
-10	14	*	20.09	54.11	**	***
0	32	*	9.44	22.07	**	***
10	50	1.42	4.70	9.78	12	1776
20	68	0.71	2.45	4.64	6.33	634
30	86	0.33	1.35	2.36	2.8	241
40	104	0.25	0.76	1.25	2	102
50	122	0.25	0.44	0.70	1	44
55	131	0.25	0.34	0.51	1	25

NOTE
1 For grassy terrain multiply the number in the chart by 0.4.
2 For grassy terrain multiply the number in the chart by 1.75.
3 For sandy terrain multiply the number in the chart by 4.5.
* Agent persistency time is less than 1 hour.
** Agent is in a frozen state and will not evaporate or decay.
*** Agent persistency time exceeds 2,000 hours.

REFERENCE BOOK 3—2*

U.S. ARMY COMMAND AND GENERAL STAFF COLLEGE
Fort Leavenworth, Kansas, *25 July 1983*

CHEMICAL WEAPONS EMPLOYMENT DATA

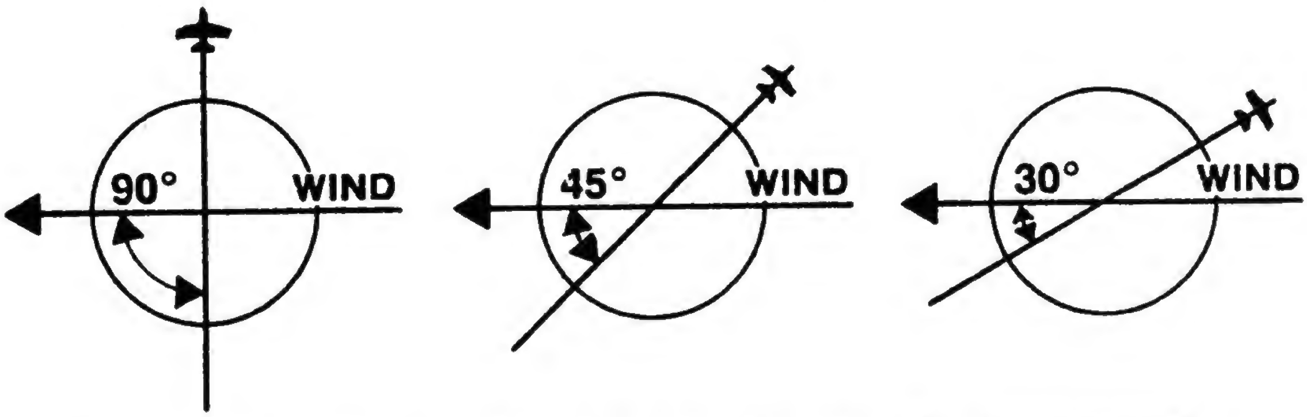
*This reference book replaces RB 3—2, 8 July 1981, for all resident and nonresident programs.

Section X
Spray Tank/VX

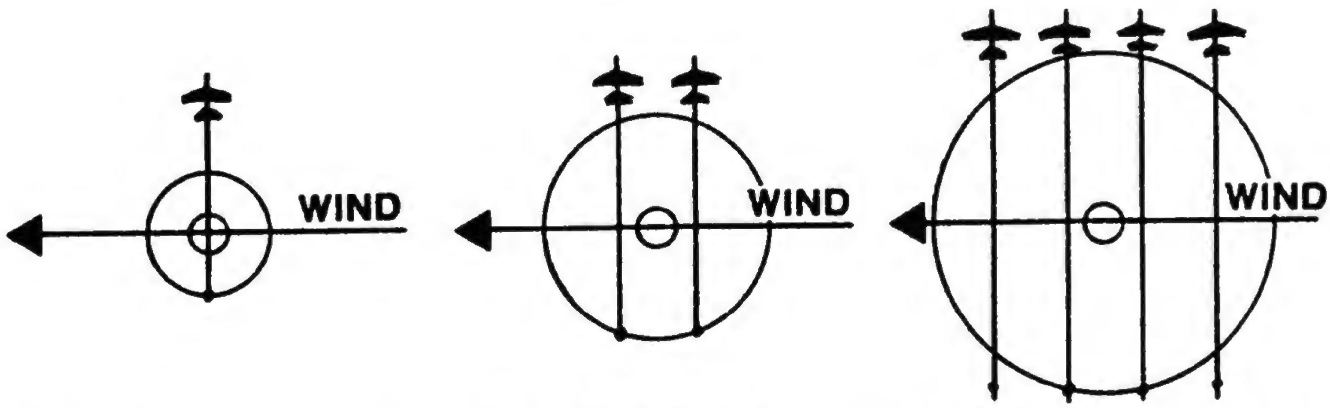
AIM POINT & FLIGHT PATH ADJUSTMENTS
VARIABLE DELIVERY TECHNIQUES

DELIVERY SYSTEM	**TANKS/AIRCRAFT**	**AIRCRAFT SPEED***
Refer to Air Force & Navy Publications	Minimum 1 Maximum 2	450 Knots Centered Delivery

$$\textbf{Altitude of Spray Release Line} = \frac{\textbf{Windspeed - Height Product (VWH)}}{\textbf{Windspeed in Knots}}$$



FLIGHT PATH IN RELATION TO WIND DIRECTION



500-M TARGET RADIUS 1,000-M TARGET RADIUS 1,500-M TARGET RADIUS

Flight path Initiation point is leading edge of target Target center

**Used on all tables in this section.*

Table I-79. Spray Tank/VX Aim Point & Flight Path Adjustments

Spray Tank/VX

Expected Fraction of Casualties

PROTECTION CATEGORY: A (NO MASK OR PROTECTIVE CLOTHING)
CASUALTIES WITHIN: 1/2 HOUR

FLOW RATE	WIND ANGLE	TARGET RADIUS (Meters)	VWH 500 NO. AIRCRAFT 1	2	4	VWH 750 NO. AIRCRAFT 1	2	4	VWH 1000 NO. AIRCRAFT 1	2	4	VWH 2000 NO. AIRCRAFT 1	2	4	VWH 3000 NO. AIRCRAFT 1	2	4
ONE TANK AT HALF FLOW	90°	500	.08	.15	.20	.17	.37	.60	.25	.46	.68	.25	.43	.60	.19	.35	.50
		1000	.01	.04	.10	.06	.15	.31	.09	.19	.45	.09	.20	.45	.09	.20	.45
		1500	–	.02	.07	–	.06	.14	–	.06	.19	–	.06	.22	–	.08	.23
	45°	500	.04	.11	.23	.13	.29	.61	.20	.41	.69	.22	.41	.64	.21	.37	.57
		1000	.01	.04	.11	.04	.10	.23	.07	.16	.36	.08	.19	.42	.08	.19	.42
		1500	–	–	.07	–	.06	.12	–	.08	.18	–	.08	.20	–	.08	.22
	30°	500	.02	.07	.16	.10	.23	.48	.15	.32	.64	.17	.36	.62	.18	.35	.57
		1000	–	.03	.08	.03	.09	.20	.06	.13	.29	.07	.15	.34	.07	.16	.36
		1500	–	–	.04	–	.04	.09	–	.06	.14	–	.08	.18	–	.08	.20
TWO TANKS AT HALF FLOW	90°	500	.08	.17	.30	.22	.46	.69	.34	.55	.69	.31	.50	.65	.25	.43	.60
		1000	.01	.05	.11	.10	.19	.41	.13	.29	.61	.15	.33	.53	.18	.35	.51
		1500	.01	.03	.10	.05	.11	.25	.07	.17	.38	.09	.20	.46	.09	.22	.49
	45°	500	.06	.13	.28	.18	.37	.71	.27	.50	.71	.30	.50	.67	.29	.47	.62
		1000	.02	.06	.13	.06	.14	.31	.11	.24	.51	.13	.29	.60	.15	.32	.63
		1500	–	.02	.08	.03	.09	.20	.06	.14	.31	.07	.17	.38	.08	.19	.42
	30°	500	.04	.09	.39	.13	.29	.73	.20	.41	.69	.23	.44	.63	.24	.43	.57
		1000	.01	.04	.10	.05	.11	.26	.09	.19	.41	.10	.23	.51	.12	.26	.56
		1500	–	.01	.06	.02	.07	.14	.04	.11	.24	.06	.13	.29	.07	.15	.34

PROTECTION CATEGORY: A (NO MASK OR PROTECTIVE CLOTHING)
CASUALTIES WITHIN: 1 HOUR

FLOW RATE	WIND ANGLE	TARGET RADIUS (Meters)	VWH 500 NO. AIRCRAFT 1	2	4	VWH 750 NO. AIRCRAFT 1	2	4	VWH 1000 NO. AIRCRAFT 1	2	4	VWH 2000 NO. AIRCRAFT 1	2	4	VWH 3000 NO. AIRCRAFT 1	2	4
ONE TANK AT HALF FLOW	90°	500	.08	.20	.27	.25	.50	.70	.36	.57	.69	.33	.53	.64	.28	.48	.58
		1000	.02	.06	.15	.10	.22	.47	.16	.34	.65	.19	.39	.65	.22	.40	.63
		1500	–	.04	.09	–	.10	.23	–	.12	.34	–	.15	.41	–	.21	.42
	45°	500	.06	.14	.30	.19	.40	.71	.28	.52	.72	.31	.52	.68	.30	.49	.64
		1000	.02	.06	.14	.07	.15	.33	.11	.25	.52	.14	.29	.55	.16	.32	.54
		1500	–	.02	.07	–	.08	.19	–	.13	.34	–	.16	.38	–	.19	.43
	30°	500	.04	.10	.22	.14	.30	.63	.21	.43	.69	.24	.45	.65	.25	.45	.59
		1000	.01	.04	.10	.05	.12	.27	.09	.19	.41	.10	.23	.48	.12	25	.49
		1500	–	.01	.05	–	.06	.14	–	.11	.24	–	.14	.31	–	.16	.37
TWO TANKS AT HALF FLOW	90°	500	.11	.24	.41	.32	.57	.74	.39	.59	.72	.35	.55	.69	.29	.47	.66
		1000	.03	.08	.19	.13	.28	.58	.21	.43	.72	.27	.49	.71	.31	.51	68
		1500	.01	.05	.14	.07	.16	.37	.12	.26	.56	.16	.34	.66	.19	39	.67
	45°	500	.08	.17	.37	.23	.48	.75	.35	.57	.72	.35	.55	.68	.32	.51	.65
		1000	.03	.08	.17	.09	.20	.42	.16	.34	.67	.20	.42	.71	.24	.47	.71
		1500	.01	.03	.10	.05	.13	.28	.09	.20	.44	.12	.26	.55	.14	.30	60
	30°	500	.05	.13	.51	.17	.37	.74	.26	.50	.71	.28	.49	65	.28	.48	.64
		1000	.02	.05	.13	.07	.16	.34	.12	.26	.55	.16	.33	.67	.18	38	.69
		1500	–	.02	.07	.03	.10	.20	.07	.15	.35	.10	.19	.43	.10	.23	.48

Table I-80. Spray Tank/VX Expected Fraction of Casualties

83-(RB 3-2)-3625

PROTECTION CATEGORY: A (NO MASK OR PROTECTIVE CLOTHING)
CASUALTIES WITHIN: ULTIMATE

FLOW RATE	WIND ANGLE	TARGET RADIUS (Meters)	WINDSPEED-HEIGHT PRODUCT (VWH) 500 NO. AIRCRAFT 1	500 2	500 4	750 NO. AIRCRAFT 1	750 2	750 4	1000 NO. AIRCRAFT 1	1000 2	1000 4	2000 NO. AIRCRAFT 1	2000 2	2000 4	3000 NO. AIRCRAFT 1	3000 2	3000 4
ONE TANK AT HALF FLOW	90°	500	.14	.31	.43	.39	.62	.74	.39	.59	.69	.35	.55	.65	.30	.50	.60
		1000	.05	.12	.26	.18	.38	.69	.30	.54	.73	.35	.56	.70	.36	.56	.68
		1500	–	.06	.15	–	.21	.42	–	.31	.56	–	.34	.59	–	.41	.59
	45°	500	.10	.23	.49	.30	.56	.75	.39	.60	.72	.36	.56	.68	.33	.53	.65
		1000	.04	.10	.22	.12	.26	.53	.19	.39	.63	.23	.43	.61	.26	.44	.59
		1500	–	.06	.12	–	.16	.33	–	.27	.54	–	.35	.62	–	.41	.65
	30°	500	.07	.16	.36	.22	.45	.74	.30	.54	.69	.31	.52	.65	.30	.50	.60
		1000	.03	.07	.16	.09	.20	.42	.14	.29	.55	.16	.34	.56	.18	.35	.55
		1500	–	.04	.09	–	.12	.25	–	.20	.45	–	.27	.55	–	.33	.59
TWO TANKS AT HALF FLOW	90°	500	.18	.38	.64	.43	.64	.75	.39	.59	.73	.35	.55	.70	.30	.50	.67
		1000	.06	.15	.30	.21	.45	.74	.35	.59	.73	.39	.60	.71	.39	.59	.69
		1500	.04	.09	.22	.13	.28	.60	.22	.46	.72	.30	.54	.74	.34	.56	.72
	45°	500	.13	.28	.58	.35	.60	.75	.40	.61	.72	.36	.56	.68	.34	.53	.65
		1000	.05	.11	.27	.16	.33	.66	.27	.52	.75	.33	.57	.73	.37	.59	.72
		1500	.03	.06	.16	.10	.21	.44	.16	.34	.65	.21	.42	.69	.24	.46	.68
	30°	500	.09	.20	.72	.26	.51	.74	.33	.56	.74	.32	.53	.70	.31	.50	.67
		1000	.04	.09	.20	.12	.26	.54	.20	.41	.73	.25	.49	.74	.29	.53	.73
		1500	.02	.04	.12	.07	.16	.32	.12	.25	.52	.15	.30	.60	.17	.34	.61

Table I-81. Spray Tank/VX Expected Fraction of Casualties

Section XI
HD Munitions

HD DOSAGE REQUIREMENTS

HD DOSAGES mg/minute/cubic meter			PERSONNEL PROTECTION CATEGORY	CASUALTY EFFECTS	DEGREE OF DISABILITY	ONSET TIME	DURATION
HOT[1]	WARM[2]	COOL[3]					
50	50	50	"A" no mask or protective clothing	No significant injury; maximum safe dosage	--	--	--
100	100	100		Eye damage of threshold military significance	PARTIAL	6-24 HR	1-3 DAYS
200	200	200		Temporary blindness	TOTAL	3-12 HR	2-7 DAYS
100	150	400	"B" or "C" with no protective clothing	No significant injury; maximum safe dosage	--	--	--
200	300	1,000		Skin burns of threshold military significance	PARTIAL	2-12 DAYS	1-2 WEEKS
500	1,000	2,000 to 4000		Severe genital burns	PARTIAL TO TOTAL	2-7 DAYS	1-4 WEEKS
750	2,000 to 4,000	4,000 to 10,000		Severe generalized burns	PARTIAL TO TOTAL	4-12 HRS About 24 HRS	3-4 WEEKS 1-2 WEEKS
			"D" mask with protective clothing	HD IS NOT RECOMMENDED FOR USE IN THIS PROTECTION CATEGORY.			

[1]Hot, humid; above 80°F; sweating skin
[2]Warm; 60°-80°F; skin not wet with sweat
[3]Cool; 40°-60°F; cool, dry skin

Table I-85. HD Munitions

HD Contamination Replenishment Time (Rate Factors)

TERRAIN FACTOR **X** WINDSPEED FACTOR **X** GROUND SURFACE TEMPERATURE FACTOR **X** TEMPERATURE GRADIENT FACTOR[2] (STABILITY) **=** TIME (HOURS) FOR 50% EVAPORATION OF HD

FACTORS

TERRAIN	WINDSPEED[1] (knots)	GROUND SURFACE TEMPERATURE (°F)	TEMPERATURE GRADIENT[2]
	1 = 3.1		
OPEN	2 = 1.8		INVERSION = 1.2
GRASSLAND = 1	3 = 1.3		
	4 = 1.0	50° = 4.0	
		60° = 2.5	
FOREST OR	5 = 0.8	70° = 1.6	NEUTRAL = 1.0
JUNGLE = 1	6 = 0.7	80° = 1.0	
	7 = 0.6	90° = 0.6	
	9 = 0.5	100° = 0.4	
	11 = 0.4	110° = 0.3	
		120° = 0.2	
BARREN SOIL	14 = 0.3		LAPSE = 0.7
OR SAND = 2	18 = 0.3		

[1]at 2 meters high in the open
[2]in the open

Table I-96. HD Contamination Replenishment Time (Rate Factors)

Approximate Duration of Hazard in Contaminated Terrain

TASK	TERRAIN	APPROXIMATE TIME AFTER CONTAMINATION THAT PRESCRIBED TASKS MAY BE PERFORMED WITH NEGLIGIBLE RISK[1] (Not wearing protective clothing)[2]			
		BLISTER AGENT (HD) TEMPERATURE[3]		NERVE AGENT (VX-GB) UNIFORM[4]	
		WARM (70°-85°F)	HOT (80°-100°F)	SUMMER	WINTER
		WEARING MASKS			
TRAVERSAL[5] (Walking across area 2 hours or less	Bare soil or low vegetation[6] (except sand)	36 HOURS	36 HOURS	5 HOURS	2 HOURS
	High vegetation, including jungle and heavy woods	4 DAYS	2 DAYS	28 HOURS	10 HOURS
		NOT WEARING MASKS[7]			
OCCUPATION (Without hitting ground 24 hours)	Bare soil or low vegetation[6] (except sand)	4 DAYS	3 DAYS	32 DAYS	13 DAYS
	High vegetation, including jungle and heavy woods	4 DAYS	3 DAYS	32 DAYS	13 DAYS
OCCUPATION (Involving advance under fire 24 hours)	Bare soil or low vegetation[6] (except sand)	4 DAYS	3 DAYS	32 DAYS	13 DAYS
	High vegetation including jungle and heavy woods	6 DAYS	4 DAYS	50 DAYS	18 DAYS

[1]These times are safe-sided for troop safety.
[2]Leather combat boots treated with protective dubbing or rubber combat boots are worn.
[3]Effects of blister agent vary significantly with temperature. Mustard freezes in temperatures below 60°F and can present a hazard when the temperature rises.
[4]Protection from V-agent and thickened G-agent varies significantly with layers of clothing worn.
[5]For personnel walking for 2 hours in an area contaminated by blister agents, the limiting factor is the vapor hazard. If only a few minutes are required for traversal of the area, the task can be initiated at earlier times than those given.
[6]Times shown are not applicable to sand, which will hold chemical agents for longer periods of time than those given.
[7]The data refer to approximate times at which personnel could occupy contaminated areas without having to wear protective masks for protection against vapor hazard.

Table I-97. Approximate Duration of Hazard in Contaminated Terrain

WARNING
This table is intended as a guide only.
Chemical agent detectors must be used to determine the extent of actual contamination and vapor hazards.

83-(RB 3-2)-3625—8635—25 Jul 83

Table 5-2. Potential Biological Warfare Agents.

Microorganism	Mode of Transmission	Incubation Period (Days)[2]	Mortality Rate (Percent)2	Vaccine ([3])	Treatment ([4])
Bacteria					
Bacillus Anthracis (Anthrax)	A, D[9], I	1-7	5-1005	+	E[6]
Francisella Tularensis (Tularemia)	A, D[9], I, V	1-10	<30	+ +	E
Yersinia Pestis (Plague)	A, V	2-6	25-1007	+ + +	E[8]
Vibrio Cholerae (Cholera)	I	1-5	15-90	+ + +	E
Corynebacterium Diptheriae (Diptheria)	A, D[9]	2-5	5-12	+ + +	E
Salmonella Typhi (Typhoid Fever)	I	6-21	7-14	+ + +	E
Rickettsiae					
Rickettsia SPP (Spotted fevers group)	V	6-15	10-40	+ + +	E
Rickettsiae (Endemic or flea-borne typhus)	V	6-14	2-5	N	E
Rickettsia (Rocky Mountain spotted fever)	V	3-10	30 (approx)	N	E
Coxiella Burnetii (Q fever)	A, I	14-21	<1	+ +	E

[1] Transmission can be by aerosol-A, direct contact-D, ingestion-I, and/or vector-V.
[2] Incubation periods and mortality rates vary according to a number of factors (such as ability of the host to resist infection, infective dose, portal of entry, and virulence of the microorganism).
[3] + indicates vaccine available but of questionable value; + + indicates vaccine available, but mainly used in high risk individuals; + + + indicates vaccine used extensively; N indicates no vaccine available.
[4] E indicates effective treatment available; N indicates no specific treatment.
[5] The mortality rate is lower when the agent enters through the skin; higher when it enters through the respiratory tract.
[6] Treatment must be initiated in the earliest stage of the pulmonary form to be effective.
[7] The 25 percent represents mortality due to bubonic form; 100 percent represents mortality due to pneumonic form.
[8] Mosquitoes are thought to be the primary vectors, but this has not been proven.
[9] Direct contact refers to being bitten by a rabid animal, which is the usual means of transmission, or coming into contact with a rabid animal.

Table 5-2. Potential Biological Warfare Agents (continued).

Microorganism	Mode of Transmission	Incubation Period (Days)[2]	Mortality Rate (Percent)2	Vaccine ([3])	Treatment ([4])
Viruses					
Eastern Equine Encephalitis (EEE)	V[8]	4-24	60 (Approx)	N	N
Venezuelan Equine Encephalitis (VEE)	V[8]	4-24	<1	+ +	N
Japanese B Encephalitis	V (Mosquito)	5-15	10-80	+ +	N
Russian SpringùSummer Encephalitis (RSSE)	V (Tick)	7-14	3-40	+	N
Yellow Fever	V (Mosquito)	3-6	5-40	+ + +	N
Dengue Fever	V (Mosquito)	4-10	<1	+	N
Pox Virus					
Variloa Virus (Smallpox)	A, D[9]	7-16	10-25	+ + +	N
Hantaan Virus (Hemorrhagic Fever with Renal Syndrome)	A, V				
Phlebovirus (Rift Valley Fever)	V (Mosquito)	4-6	<1	N	N
Nairovirus (Crimean-Congo Hemorrnagil Fever)	V (Tick)	3-7			
Bunyavirus (LA Crosse)	V (Mosquito)				
Phlebovirus(Sandfly)	V (Sand fly)	3-6			

1 Transmission can be by aerosol-A, direct contact-D, ingestion-I, and/or vector-V.
2 Incubation periods and mortality rates vary according to a number of factors (such as ability of the host to resist infection, infective dose, portal of entry, and virulence of the microorganism).
3 + indicates vaccine available but of questionable value; + + indicates vaccine available, but mainly used in high risk individuals; + + + indicates vaccine used extensively; N indicates no vaccine available.
4 E indicates effective treatment available; N indicates no specific treatment.
5 The mortality rate is lower when the agent enters through the skin; higher when it enters through the respiratory tract.
6 Treatment must be initiated in the earliest stage of the pulmonary form to be effective.
7 The 25 percent represents mortality due to bubonic form; 100 percent represents mortality due to pneumonic form.
8 Mosquitoes are thought to be the primary vectors, but this has not been proven.
9 Direct contact refers to being bitten by a rabid animal, which is the usual means of transmission, or coming into contact with a rabid animal.

Table 5-3. Threat Toxins.

Type of Toxin	Means of ID	Symptoms in Man	Effects on Man	Rate of Action	How Normally Disseminated	Protection Required	Decontamination
Mycotoxins	None	Vomiting, eye and skin irritation, dizziness, bloody diarrhea, and blisters.	Can incapacitate or kill, depending on concentration.	Rapid	Dusts, droplets, aerosols, smokes, or covert means	Protective mask and protective clothing	Soap and water, bleach, M258-series kit, STB and DS2
Enterotoxins	None	Severe vomiting and diarrhea, painful cramps, and weakness	Primarily incapacitates, assuming proper first aid is conducted	Same as above	Same as above	Same as above	Same as above
Botulinum Toxin	None	Double vision, weakness, difficulty in speech and swallowing, and respiratory paralysis	Kills	Delayed	Same as above	Same as above	Same as above

POTENTIAL MILITARY CHEMICAL/BIOLOGICAL AGENTS AND COMPOUNDS, US Army FM 3-11.9, 2005

Table G-4. Toxicity Estimates for CW Agents

ROE		Liquid (mg/70 kg man)		Inhalation/Ocular ($mg\text{-}min/m^3$)			Inhalation (mg/m^3)	Ocular ($mg\text{-}min/m^3$)		Percutaneous Vapor ($mg\text{-}min/m^3$)			
Endpoints		Lethal (LD_{50})	Severe (ED_{50})	Lethal (LCt_{50})	Severe (ECt_{50})	Mild (ECt_{50})	Odor Detection (EC_{50})	Severe (ECt_{50})	Mild (ECt_{50})	Lethal (LCt_{50}) Moderate	Lethal (LCt_{50}) Hot	Severe (ECt_{50}) Moderate	Severe (ECt_{50}) Hot
Choking Agents	CG	-	-	1,500 (2-60)	-	-	6 S	-	-	-	-	-	-
	DP	-	-	1,500P (10-60)	-	-	4 S	-	-	-	-	-	-
Nerve Agents	GA	1,500	900	70 (2)	50 (2)	0.4 (2)	-	-	-	15,000 (30-360)	7,500P (30-360)	12,000 (30-360)	6,000P (30-360)
	GB	1,700	1,000	35 (2)	25 (2)	0.4 (2)	-	-	-	12,000 (30-360)	6,000P (30-360)	8,000 (30-360)	4,000P (30-360)
	GD	350	200	35 (2)	25 (2)	0.2 (2)	-	-	-	3,000 (30-360)	1,500P (30-360)	2,000 (30-360)	1,000P (30-360)
	GF	350	200	35 (2)	25 (2)	0.2 (2)	-	-	-	3,000 (30-360)	1,500P (30-360)	2,000 (30-360)	1,000P (30-360)
	VX	5	2	15 (2-360)	10 (2-360)	0.1 (2-360)	-	-	-	150 (30-360)	75P (30-360)	25 (30-360)	12P (30-360)
	Vx	NR											
Blood Agent	AC	-	-	2860P (2)	NR		34 S	-	-	-	-	-	-
	CK	-	-	NR	NR		12 S	-	-	-	-	-	-
	SA	-	-	7,500P (2)	-	-	-	-	-	-	-	-	-
Blister Agents	HD	1400	600	1,000 (2)	-	-	0.6 – 1 S	75 (2-360)	25 (2-360)	10,000 (30-360)	5,000P (30-360)	500 (30-360)	200 (30-360)
	HN-1	1400P	600P	1,000P (2)	-	-	-	75P (2)	25P (2)	10,000P (30)	5,000P (30)	500P (30)	200P (30)
	HN-2	1400P	600P	1,000P (2)	-	-	-	75P (2)	25P (2)	10,000P (30)	5,000P (30)	500P (30-360)	200P (30-360)
	HN-3	1400P	600P	1,000P (2-360)	-	-	-	75P (2-360)	25P (2-360)	10,000P (30-360)	5,000P (30-360)	500P (30-360)	200P (30-360)
	HT	1400P	600P	1,000P (2-360)	-	-	-	75P (2-360)	25P (2-360)	10,000P (30-360)	5,000P (30-360)	500P (30-360)	200P (30-360)
	L	1400P	600P	1,000P (2-360)	-	-	8 S	75P (2-360)	25P (2-360)	5,000 - 10,000P (30-360)	2,500 - 5,000P (30-360)	500P (30-360)	200P (30-360)
	HL	1400P	600P	1,000P (2-360)	-	-	2 S	75P (2-360)	25P (2-360)	10,000P (30-360)	5,000P (30-360)	500P (30-360)	200P (30-360)

COMPARATIVE VOLATILITY OF CHEMICAL WARFARE AGENTS

Agent	Volatility (mg/m^3) at 25°C
Hydrogen cyanide (HCN)	1,000,000
Sarin (GB)	22,000
Soman (GD)	3,900
Sulfur mustard	900
Tabun (GA)	610
Cyclosarin (GF)	580
VX	10
VR ("Russian VX")	9

Data source: US Departments of the Army, Navy, and Air Force. *Potential Military Chemical/Biological Agents and Compounds*. Washington, DC: Headquarters, DA, DN, DAF; December 12, 1990. Field Manual 3-9. Naval Facility Command P-467. Air Force Regulation 355-7.

SIGNS AND SYMPTOMS REPORTED BY TOKYO HOSPITAL WORKERS TREATING VICTIMS OF SARIN SUBWAY ATTACKS*

Symptom	Number/percentage of the 15 physicians who treated patients at UH		Number/percentage of 472 care providers reporting symptoms at SLI	
Dim vision	11	73%	66	14%
Rhinorrhea	8	53%	No information	
Dyspnea (chest tightness)	4	27%	25	5.3%
Cough	2	13%	No information	
Headache	No information		52	11%
Throat pain	No information		39	8.3%
Nausea	No information		14	3.0%
Dizziness	No information		12	2.5%
Nose pain	No information		6	1.9%

*Data reflect reported survey of self-reported symptomatology of physicians at the University Hospital of Metropolitan Japan emergency department and all hospital workers at Saint Luke's International Hospital exposed to sarin vapors from victims of the Tokyo subway attack.

SLI: Saint Luke's International Hospital

UH: University Hospital

Data sources: (1) Nozaki H, Hori S, Shinozawa Y, et al. Secondary exposure of medical staff to sarin vapor in the emergency room. *Intensive Care Med*. 1995;21:1032-1035. (2) Okumura T, Suzuki K, Fukuda A, et al. The Tokyo subway sarin attack: disaster management, Part 1: community emergency response. *Acad Emerg Med*. 1998;5:613-617. (3) Okumura T, Suzuki K, Fukuda A, et al. The Tokyo subway sarin attack: disaster management, Part 2: Hospital response. *Acad Emerg Med*. 1998;5:618-624.

TABLE 21-3

MANAGEMENT OF MILD TO MODERATE NERVE AGENT EXPOSURES

		Management			
		Antidotes*		Benzodiazepines (if neurological signs)	
Nerve Agents	**Symptoms**	**Age**	**Dose**	**Age**	**Dose**
• Tabun • Sarin • Cyclosarin • Soman • VX	• Localized sweating • Muscle fasciculations • Nausea • Vomiting • Weakness/floppiness • Dyspnea • Constricted pupils and blurred vision • Rhinorrhea • Excessive tears • Excessive salivation • Chest tightness • Stomach cramps • Tachycardia or bradycardia	Neonates and infants up to 6 months old	**Atropine** 0.05 mg/kg IM/IV/IO to max 4 mg or 0.25 mg AtroPen† and **2-PAM** 15 mg/kg IM or IV slowly to max 2 g/hr	Neonates	**Diazepam** 0.1–0.3 mg/kg/dose IV to a max dose of 2 mg, or **Lorazepam** 0.05 mg/kg slow IV
		Young children (6 months old–4 yrs old)	**Atropine** 0.05 mg/kg IM/IV/IO to max 4 mg or 0.5 mg AtroPen and **2-PAM** 25 mg/kg IM or IV slowly to max 2 g/hr	Young children (30 days old–5 yrs old)	**Diazepam** 0.05–0.3 mg/kg IV to a max of 5 mg/dose or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
				Children (≥ 5 yrs old)	**Diazepam** 0.05–0.3 mg/kg IV to a max of 10 mg/dose or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
		Older children (4–10 yrs old)	**Atropine** 0.05 mg/kg IV/IM/IO to max 4 mg or 1 mg AtroPen and **2-PAM** 25–50 mg/kg IM or IV slowly to max 2 g/hr	Adolescents and adults	**Diazepam** 5–10 mg up to 30 mg in 8 hr period or **Lorazepam** 0.07 mg/kg slow IV not to exceed 4 mg
		Adolescents (≥ 10 yrs old) and adults	**Atropine** 0.05 mg/kg IV/IM/IO to max 4 mg or 2 mg AtroPen and **2-PAM** 25–50 mg/kg IM or IV slowly to max 2 g/hr		

2-PAM: 2-pralidoxime
IM: intramuscular
IO: intraosseous
IV: intraveneous
PDH: Pediatrics Dosage Handbook
*In general, pralidoxime should be administered as soon as possible, no longer than 36 hours after the termination of exposure. Pralidoxime can be diluted to 300 mg/mL for ease of intramuscular administration. Maintenance infusion of 2-PAM at 10–20 mg/kg/hr (max 2 g/hr) has been described. Repeat atropine as needed every 5–10 minutes until pulmonary resistance improves, secretions resolve, or dyspnea decreases in a conscious patient. Hypoxia must be corrected as soon as possible.
†Meridian Medical Technologies Inc, Bristol, Tenn.
Data sources: (1) Rotenberg JS, Newmark J. Nerve agent attacks on children: diagnosis and management. *Pediatrics*. 2003;112:648–658. (2) Pralidoxime [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2002. (3) AtropPen (atropine autoinjector) [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2004. (4) Henretig FM, Cieslak TJ, Eitzen Jr EM. Medical progress: biological and chemical terrorism. *J Pediatr*. 2002;141(3):311–326. (5) Taketomo CK, Hodding JH, Kraus DM. *American Pharmacists Association: Pediatric Dosage Handbook*. 13th ed. Hudson, Ohio; Lexi-Comp Inc: 2006.

TABLE 21-4

MANAGEMENT OF SEVERE NERVE AGENT EXPOSURE

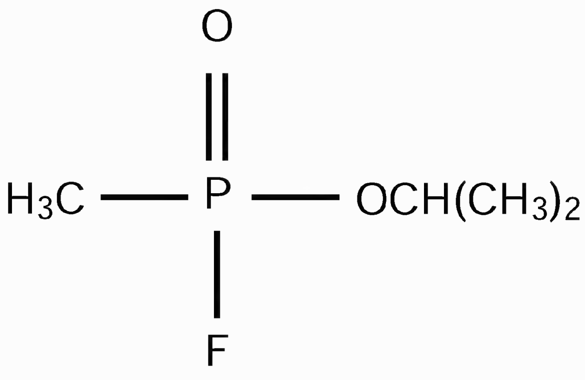
		Management			
		Antidotes*		Benzodiazepines (if neurological signs)	
Nerve Agents	Severe Symptoms	Age	Dose	Age	Dose
• Tabun • Sarin • Cyclosarin • Soman • VX	• Convulsions • Loss of consciousness • Apnea • Flaccid paralysis • Cardio-pulmonary arrest • Strange and confused behavior • Severe difficulty breathing • Involuntary urination and defecation	Neonates and infants up to 6 months old	**Atropine** 0.1 mg/kg IM/IV/IO or 3 doses of 0.25mg AtroPen[†] (administer in rapid succession) and **2-PAM** 25 mg/kg IM or IV slowly, or 1 Mark I[†] kit (atropine and 2-PAM) if no other options exist	Neonates	**Diazepam** 0.1–0.3 mg/kg/dose IV to a max dose of 2 mg, or **Lorazepam** 0.05 mg/kg slow IV
		Young children (6 months old–4 yrs old)	**Atropine** 0.1 mg/kg IV/IM/IO or 3 doses of 0.5mg AtroPen (administer in rapid succession) and **2-PAM** 25–50 mg/kg IM or IV slowly, or 1 Mark I kit (atropine and 2-PAM) if no other options exist	Young children (30 days old–5 yrs and adults	**Diazepam** 0.05–0.3 mg/kg IV to a max of 5 mg/dose, or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
		Older children (4–10 yrs old)	**Atropine** 0.1 mg/kg IV/IM/IO or 3 doses of 1mg AtroPen (administer in rapid succession) and **2-PAM** 25–50 mg/kg IM or IV slowly, 1 Mark I kit (atropine and 2-PAM) up to age 7, 2 Mark I kits for ages > 7–10 yrs	Children (≥ 5 yrs old)	**Diazepam** 0.05-0.3 mg/kg IV to a max of 10 mg/dose, or **Lorazepam** 0.1 mg/kg slow IV not to exceed 4 mg
		Adolescents (≥ 10 yrs old) and adults	**Atropine** 6 mg IM or 3 doses of 2 mg AtroPen (administer in rapid succession) and **2-PAM** 1800 mg IV/IM/IO, or 2 Mark I kits (atropine and 2-PAM) up to age 14, 3 Mark I kits for ages ≥ 14 yrs	Adolescents and adults	**Diazepam** 5–10 mg up to 30 mg in 8-hr period, or **Lorazepam** 0.07 mg/kg slow IV not to exceed 4 mg

IM: intramuscular
IO: intraosseous
IV: intravenous

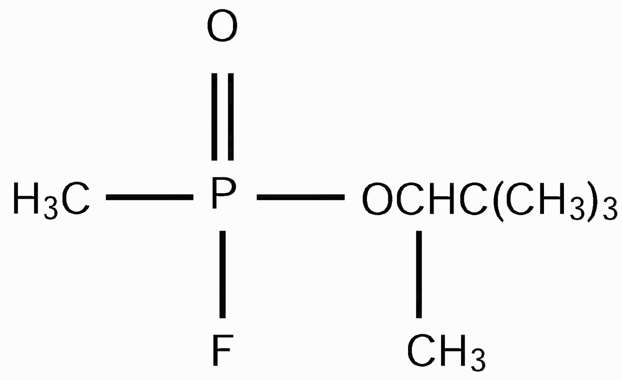
*In general, pralidoxime should be administered as soon as possible, no longer than 36 hours after the termination of exposure. Pralidoxime can be diluted to 300 mg/mL for ease of intramuscular administration. Maintenance infusion of 2-PAM at 10–20 mg/kg/hr (max 2 g/hr) has been described. Repeat atropine as needed every 5–10 min until pulmonary resistance improves, secretions resolve, or dyspnea decreases in a conscious patient. Hypoxia must be corrected as soon as possible. [†]Meridian Medical Technologies Inc, Bristol, Tenn.

Data sources: (1) Rotenberg JS, Newmark J. Nerve agent attacks on children: diagnosis and management. *Pediatrics*. 2003;112:648–658. (2) Pralidoxime [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2002. (3) AtroPen (atropine autoinjector) [package insert]. Bristol, Tenn: Meridian Medical Technologies, Inc; 2004. (4) Henretig FM, Cieslak TJ, Eitzen Jr EM. Medical progress: biological and chemical terrorism. *J Pediatr*. 2002;141(3):311–326. (5) Taketomo CK, Hodding JH, Kraus DM. *American Pharmacists Association: Pediatric Dosage Handbook*. 13th ed. Hudson, Ohio: Lexi-Comp Inc; 2006.

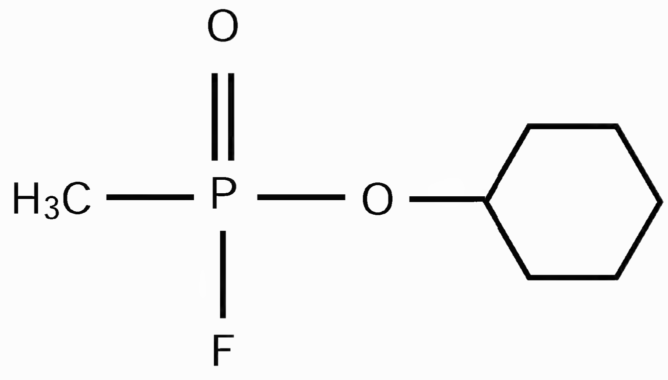
Sarin (GB)



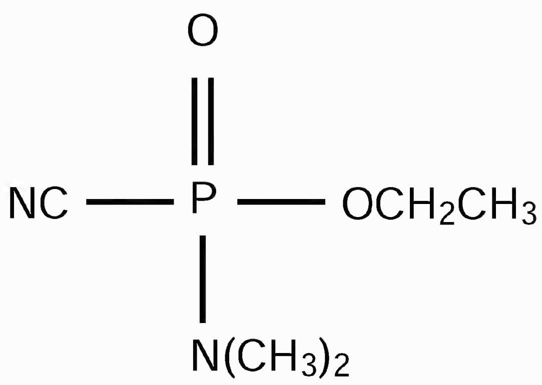
Soman (GD)



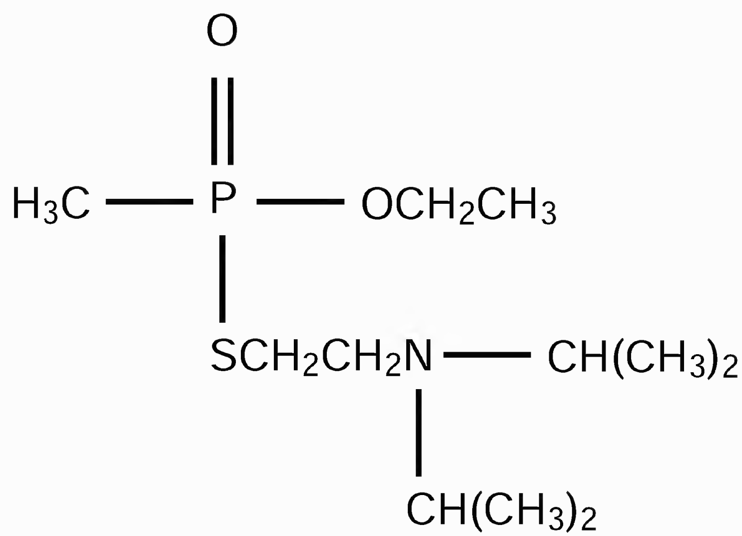
Cyclosarin (GF)



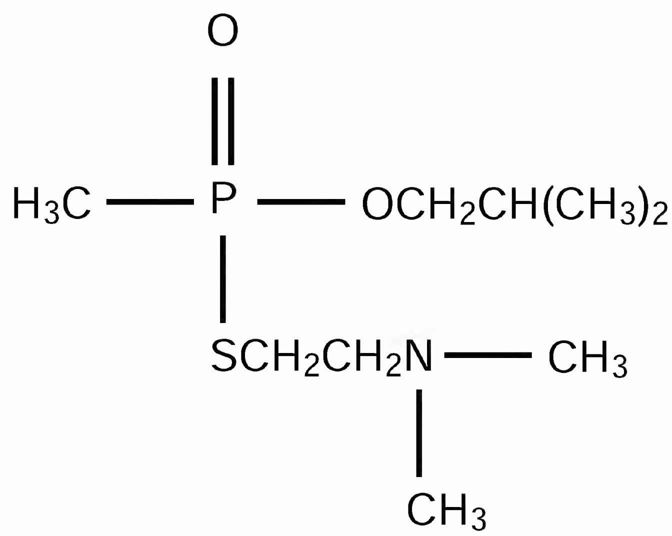
Tabun (GA)



VX



Russian VX



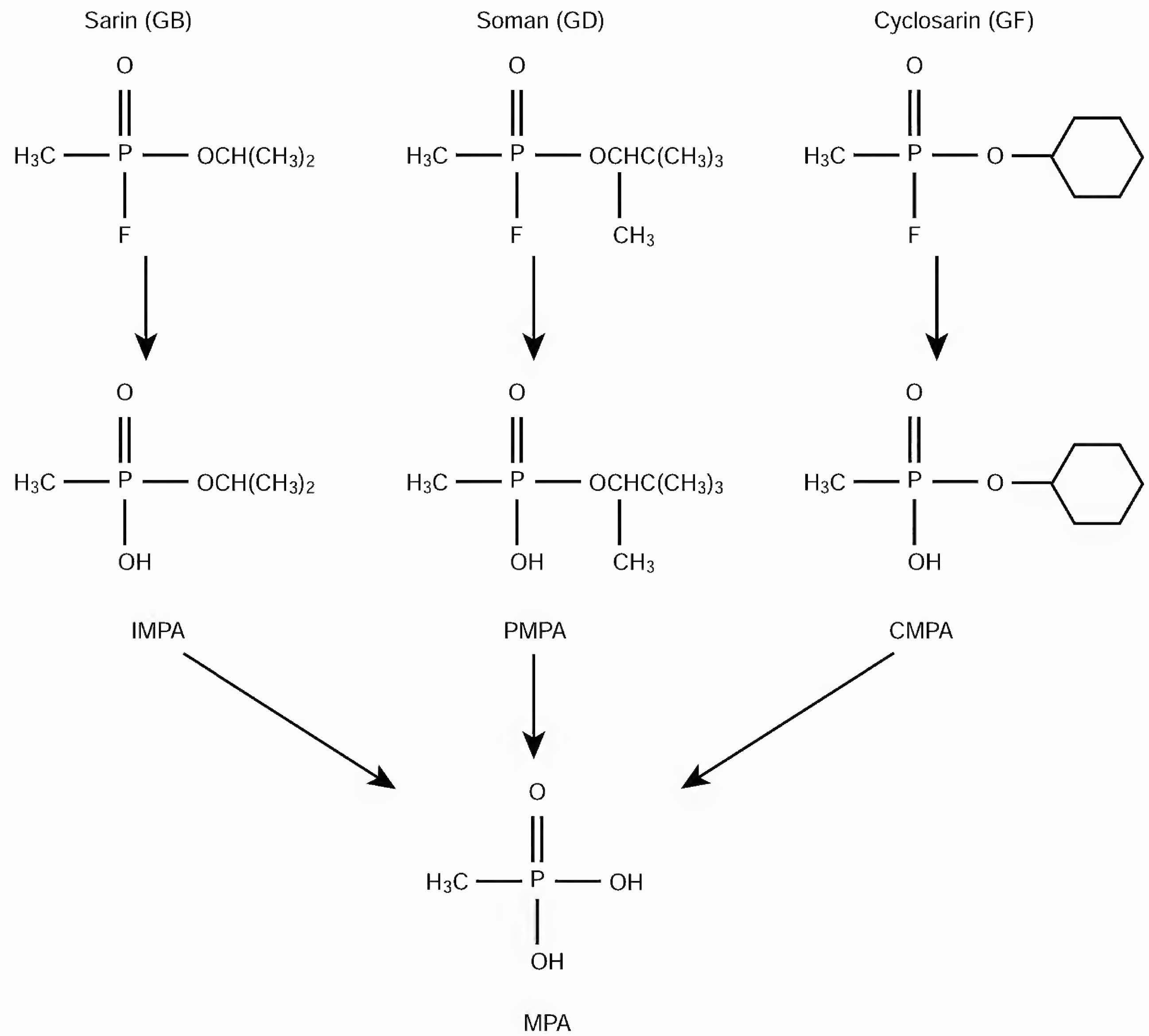


Fig. 22-2. Hydrolysis pathway of sarin (GB), soman (GD), and cyclosarin (GF). Hydrolysis pathway of nerve agents proceeds through the alkyl methylphosphonic acids IMPA, PMPA, and CMPA to MPA. Analysis of the alkyl methylphosphonic acids allows identification of the parent agent, while assay of MPA is nonspecific.
CMPA: cyclohexyl methylphosphonic acid
IMPA: isopropyl methylphosphonic acid
MPA: methylphosphonic acid
PMPA: pinacolyl methylphosphonic acid

TECHNICAL MANUAL No. 3-400
TECHNICAL ORDER No. 11C2-1-1

DEPARTMENTS OF THE ARMY AND THE AIR FORCE
WASHINGTON 25, D. C., *8 May 1957*

CHEMICAL BOMBS AND CLUSTERS

* This manual supersedes TM 3-400, 28 April 1953.

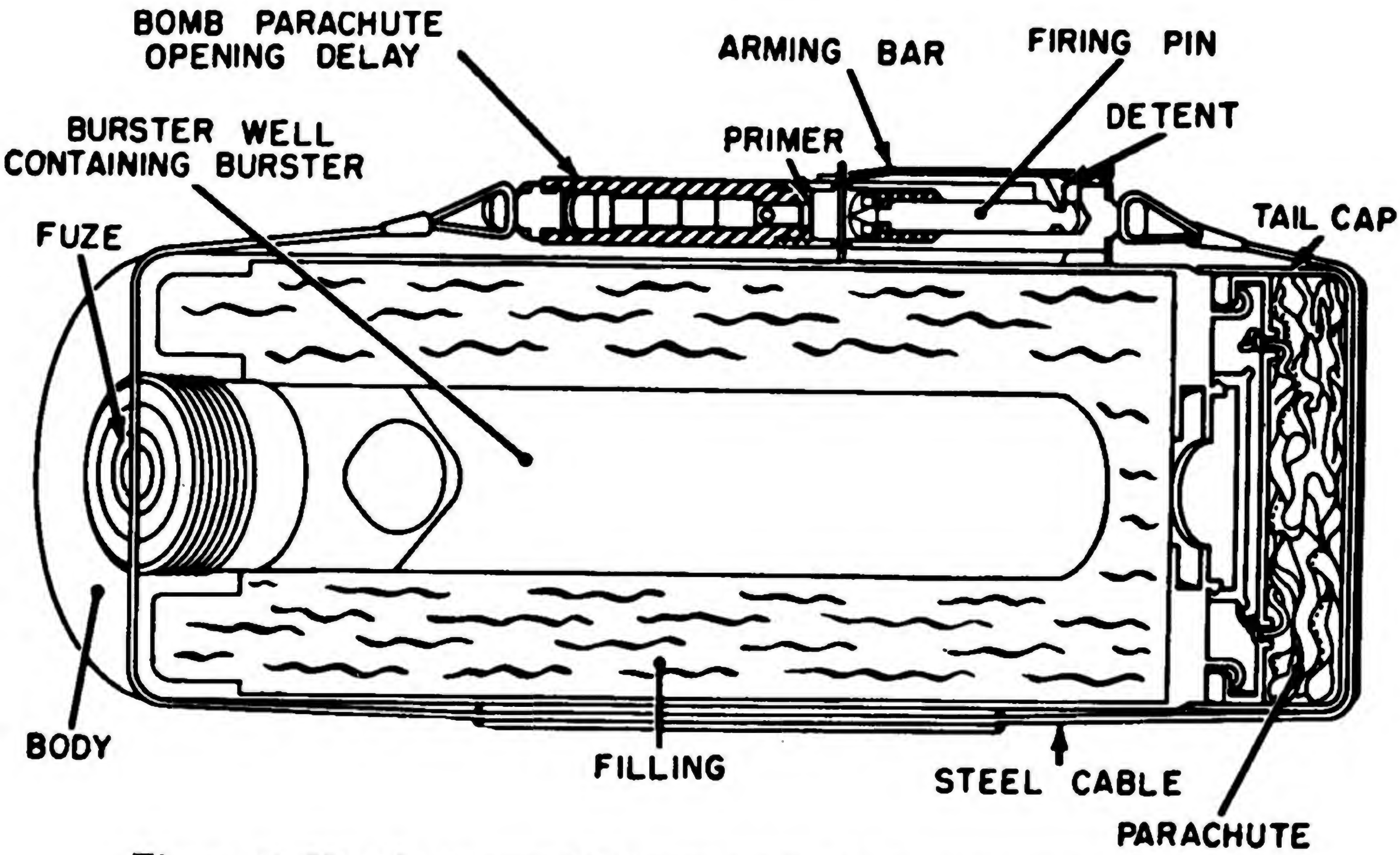


Figure 24. M125A1 10-pound GB nonpersistent gas bomb, sectional view.

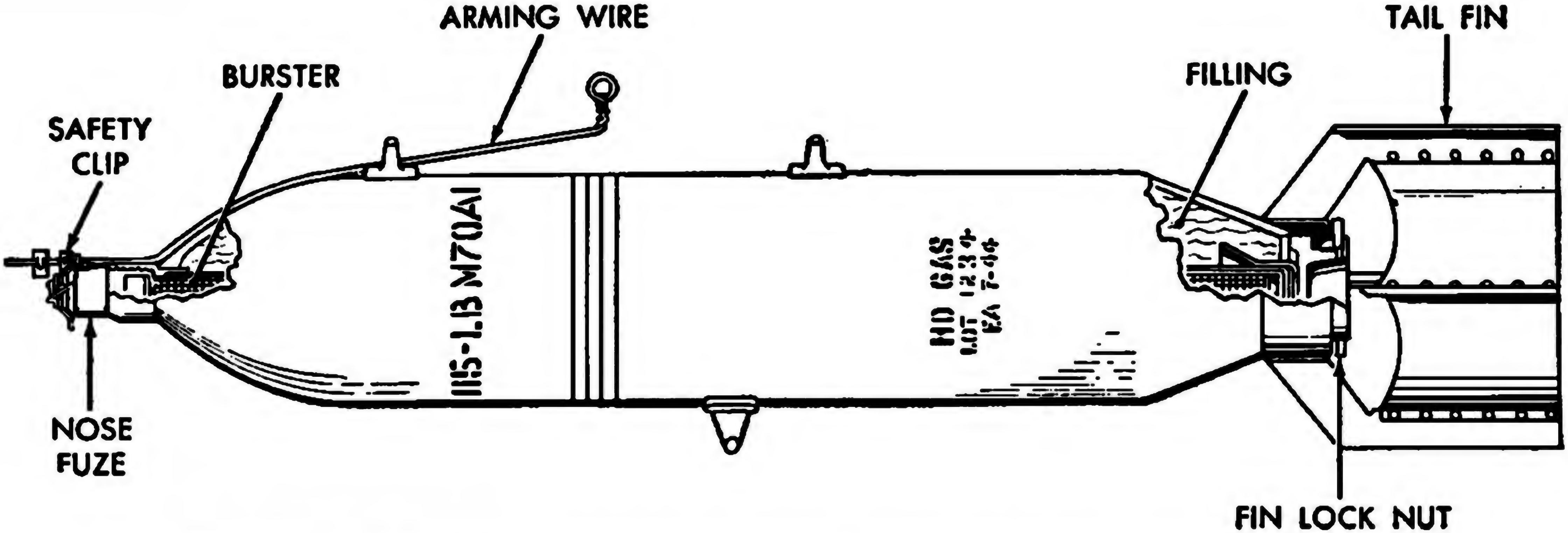


Figure 26. M70A1 115-pound HD persistent gas bomb, cutaway view.

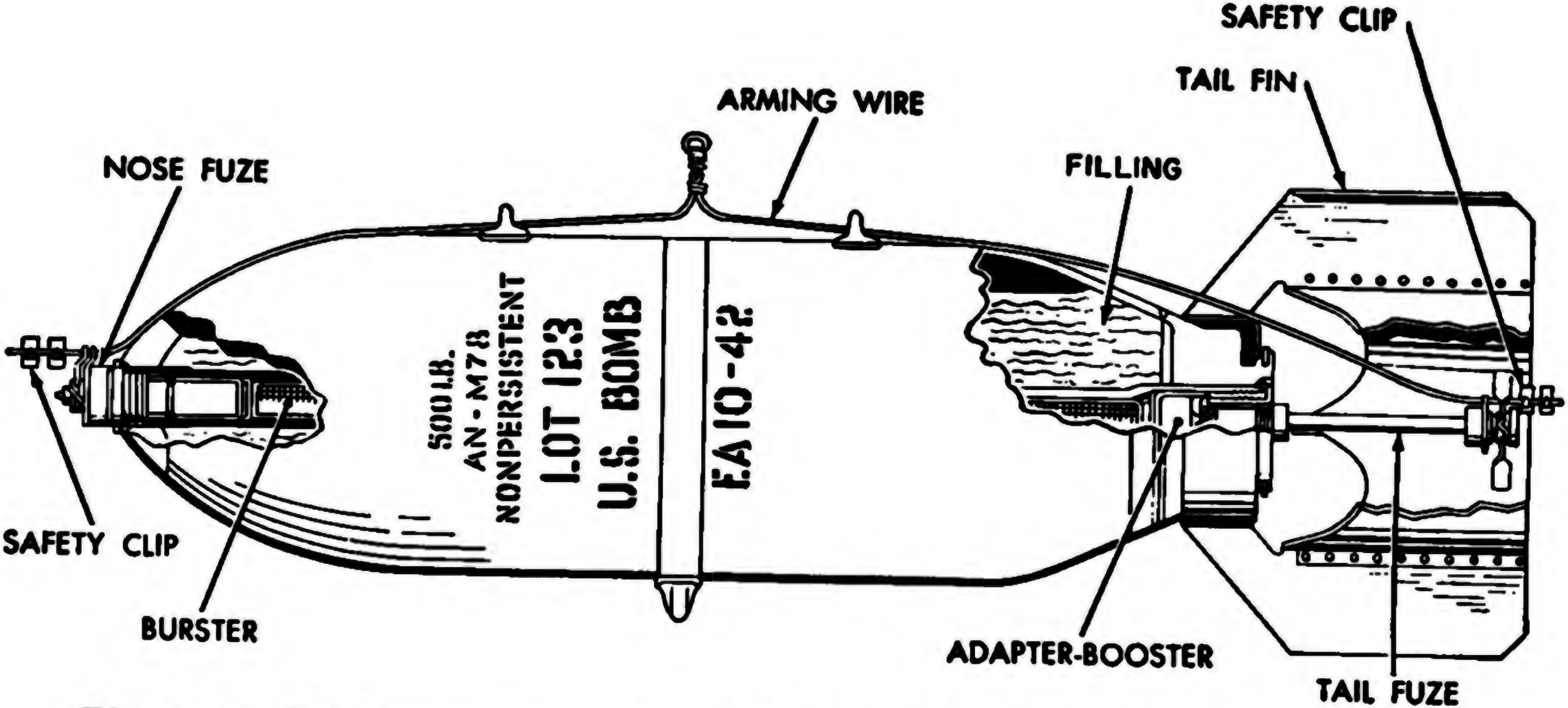


Figure 28. AN–M78 500-pound CG or CK nonpersistent gas bomb, cutaway view.

M139 (E130R2) bomblet.

The 762-millimeter M190 Honest John GB warhead. Developed as the E19R2, it carried 356 115-millimeter M134 (E130R1) spherical bomblets. The overall fill efficiency of the M190 was 37%. Range 8.5-33.8 km, bomblets released at 5 kft altitude to give a 1 km diameter area coverage.

Reid Kirby, "The CB Battlefield Legacy", Army Chemical Review, July–December 2006, pp. 25-29.

It may be several weeks or even months before I shall ask you to drench Germany with poison gas, and if we do it, let us do it one hundred per cent. In the meanwhile, I want the matter to be studied in cold blood by sensible people and not by that particular set of psalm-singing uninformed defeatists which one runs across now here, now there (Churchill 1944).

Gilbert M (1991). *Churchill. A Life*, pp. 782–783. London: Heinemann.

ADA488135

USAWC RESEARCH ELEMENT
(Research Paper)

What's Wrong With Gas Warfare?

by

Lt Col Stanley D. Fair
Chemical Corps

US Army War College
Carlisle Barracks, Pennsylvania
8 April 1966

PUBLIC INFORMATION PROGRAM

A new national policy on gas warfare such as the one presented above can provide the necessary guidance for the people as to the importance of gas weapons and their role. The formulation of policy must precede or accompany any attempt to educate the public on gas warfare since "public knowledge of facts is not understanding until it can be set in the framework of policy and goals."[11]

Public resistance to a new policy may occur because of false impressions about gas warfare. Since the American people have considerable influence on adoption of policy, they must be provided objective information on gas warfare. As "Elihu Root...wrote... when policy on foreign affairs is largely dominated by the people, the danger lies in mistaken beliefs and emotions."[12]

The issue of gas warfare is emotional and political. In this respect it is similar to many issues facing our government today; communism and race relations are examples. Government officials have led the way with free and open discussions on these controversial subjects and should do the same with gas warfare. This leadership is essential, as Major General W.M. Creasy warned a House Science Committee in 1959:

---

[11] "Public Understanding--The Ultimate Weapon?" The General Electric Defense Quarterly, Vol. 3, Oct.-Dec. 1960, p. 33.

[12] William Albig, Modern Public Opinion, p. 12.

Albig, William. Modern Public Opinion. New York: McGraw-Hill, 1956. (HM261 A451)

> I do not believe the American people are going to read any information on a subject when the American government says this is too horrible to use and we are not going to use it.[13]

The first step in a public information program is to go after the roots of public hostility towards gas warfare: World War I propaganda. The effects of the Allied propaganda did not evaporate with the gas clouds of World War I "for that half-century-old vision of the blue-faced men at Ypres choking to death, has left an indelible impression upon the mind of the world."[14] As late as 1953 the horrors of the first gas attack were brought out in the memoirs of a war correspondent who served with the Red Cross at Ypres:

> This horror was too monstrous to believe at first... the savagery of it, of the sight of men choking to death with yellow froth, lying on the floor and out in the fields, made me rage with an anger which no later cruelty of man...ever quite rekindled; for then we still thought all men were human.[15]

The tragedy of the first gas attack should be admitted in any program of public information: the soldiers were helpless; those who did not panic and run suffered a slow and painful death. On the other hand, it should be pointed out that protection against chlorine was simple and was achieved before the second gas attack took place two days later. Ypres was an isolated incident.

---

[13]Quoted in US Congress, House, Committee on Science and Astronautics, Chemical, Biological and Radiological Warfare Agents, p. 22.

[14]Hanson W. Baldwin, "After Fifty Years the Cry of Ypres Still Echoes--'GAS!'," New York Times Magazine, 18 Apr. 1965, p. 50.

[15]Geoffrey W. Young, The Grace of Forgetting, p. 233.

The best counter to propaganda is to tell the truth. In getting the facts to the public it is important to differentiate between information which can and cannot be made available to the public. They should know in general what is going on, but the details must remain classified to protect national security. It is important also to differentiate between information which should and should not be made available to the public. Articles on gas warfare should pass the test of one criterion before release by the Department of Defense: does it contribute to public understanding of gas warfare, or does it add to the misconceptions of mystery and indecency?

The free and open discussion on nuclear warfare has resulted in the willingness of the responsible American to accept the nuclear weapon as an unpleasant fact, essential to his country's safety. The current secrecy surrounding gas warfare can create a lack of confidence in the capabilities of gas. Captain Liddell Hart told of British tanks developed during World War II that were fitted with special searchlights for blinding the enemy as well as for night firing. This invention was "kept so secret that the commanders in the field regarded them distrustfully and thus repeatedly hesitated to employ such unfamiliar instruments."[19]

---

[19] B.H. Liddell Hart, Deterrent of Defense, pp. 86-87.

CIVIL DEFENCE

why we need it

Message from the Home Secretary and the Secretary of State for Scotland

For over 30 years our country, with our allies, has sought to avoid war by deterring potential aggressors. Some disagree as to the means we should use. But whatever view we take, we should surely all recognise the need – and indeed the duty – to protect our civil population if an attack were to be made upon us; and therefore to prepare accordingly.

The Government is determined that United Kingdom civil defence shall go ahead. The function of civil defence is not to encourage war, or to put an acceptable face on it. It is to adapt ourselves to the reality that we at present must live with, and to prepare ourselves so that we could alleviate the suffering which war would cause if it came.

Even the strongest supporter of unilateral disarmament can consistently give equal support to civil defence, since its purpose and effect are essentially humane.

William Whitelaw George Younger

Why bother with civil defence?

Why bother with wearing a seat belt in a car? Because a seat belt is reckoned to lessen the chance of serious injury in a crash. The same applies to civil defence in peacetime.

War would be horrific. Everyone knows the kind of devastation and suffering it could cause. But while war is a possibility – however slight – it is right to take measures to help the victims of an attack, whether nuclear or 'conventional'.

But isn't it a waste of money in these days of nuclear weapons and the dreadful prospects of destruction?

No. It is money well spent if it shows people how they can safeguard themselves and their families.

But surely there is no real protection against a nuclear attack?

Millions of lives could be saved, by safeguards against radiation especially. But civil defence is not just protection against a nuclear attack. It is protection against *any* sort of attack. NATO experts reckon that any war involving the UK is likely at least to start with non-nuclear weapons. Indeed, while no war is likely so long as we maintain a credible deterrent, the likelihood of a nuclear war is less than that of a 'conventional' one.

But doesn't civil defence get people more war-minded, thus increasing the risk of conflict?

That is like saying people who wear seat belts are expecting to have more crashes than those who do not. Taking civil defence seriously means seeking to save lives in the catastrophe of an attack on our country.

To Sum Up

The case for civil defence stands regardless of whether a nuclear deterrent is necessary or not. Radioactive fallout is no respecter of neutrality. Even if the UK were not itself at war, we would be as powerless to prevent fallout from a nuclear explosion crossing the sea as was King Canute to stop the tide. This is why countries with a long tradition of neutrality (such as Switzerland and Sweden) are foremost in their civil defence precautions.

Civil defence is common sense

Further information:

Nuclear Weapons
ISBN 0 11 34055 X — HMSO £3.50 (net)

Protect and Survive
ISBN 0 11 3407289 — HMSO 50p (net)

Domestic Nuclear Shelters
ISBN 0 11 3407378 — HMSO 50p (net)

Domestic Nuclear Shelters – Technical Guidance
ISBN 0 11 34073786 — HMSO £5.50 (net)

HOME OFFICE

SCOTTISH HOME DEPARTMENT

MANUAL OF CIVIL DEFENCE

Volume I

PAMPHLET No. 1

NUCLEAR WEAPONS

LONDON

HER MAJESTY'S STATIONERY OFFICE

1956

Practical protection

88 Large buildings with a number of storeys, especially if they are of heavy construction, provide much better protection than small single-storey structures (see Figure 4). Houses in terraces likewise provide much better protection than isolated houses because of the shielding effect of neighbouring houses.

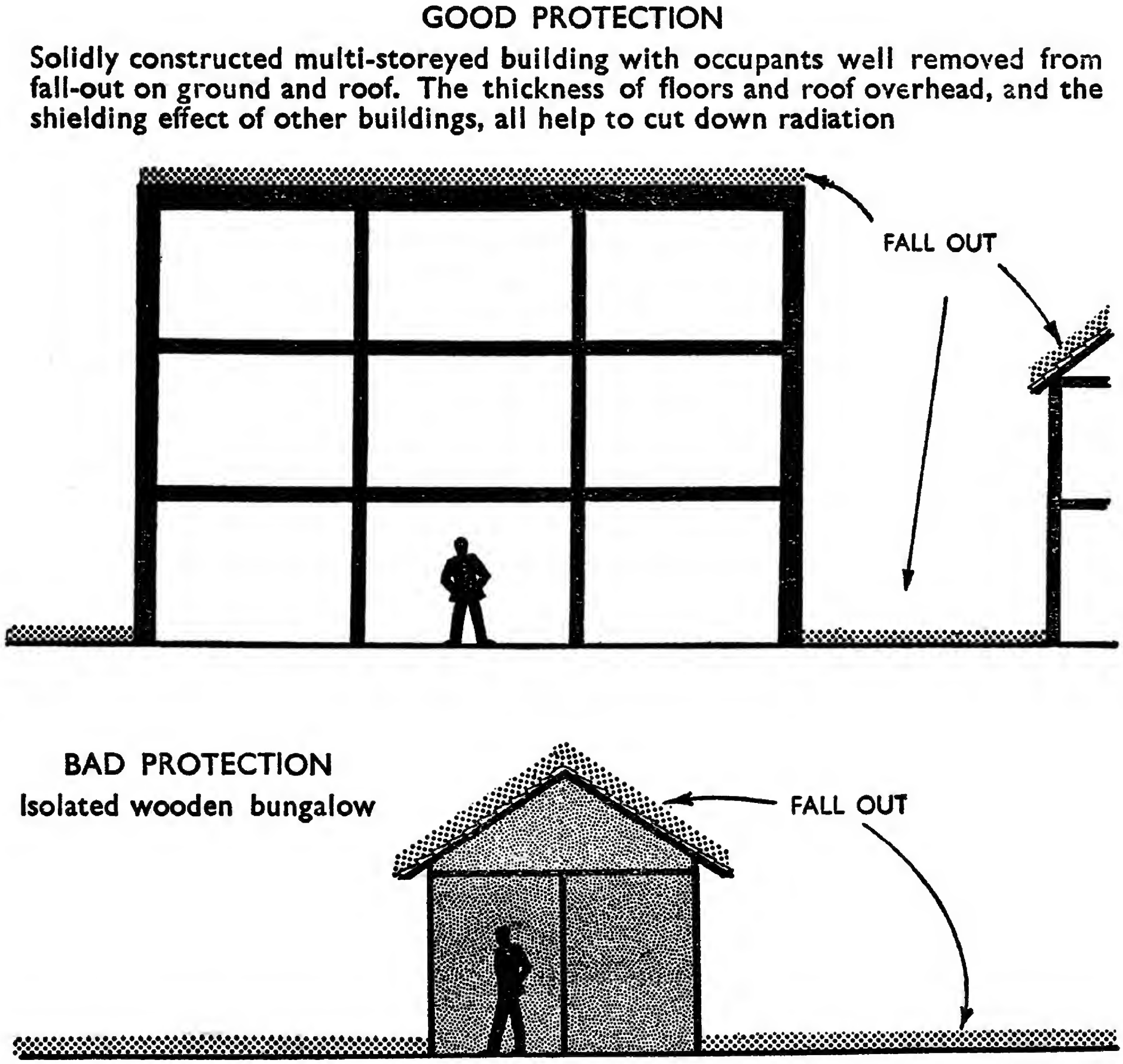


FIGURE 4

Examples of good and bad protection afforded by buildings against fall-out.

89 It is estimated that the protection factor (the factor by which the outside dose has to be divided to get the inside dose) of a ground floor room in a two-storey house ranges from 10 to about 50, depending on wall thickness and the shielding afforded by neighbouring buildings. The corresponding figures for bungalows are about 10–20, and for three-storey houses about 15–100. An average two-storey brick house in a built-up area gives a factor of 40, but basements, where the radiation from outside the house is attenuated by a very great thickness of earth, have protection factors ranging up to 200–300. A slit trench with even a light cover of boards or corrugated iron without earth overhead gives a factor of 7, and if 1 ft. of earth cover is added the

factor rises to 100. If the trench can be covered with 2 or 3 feet of earth then a factor of more than 200–300 can be obtained (see Figure 5).

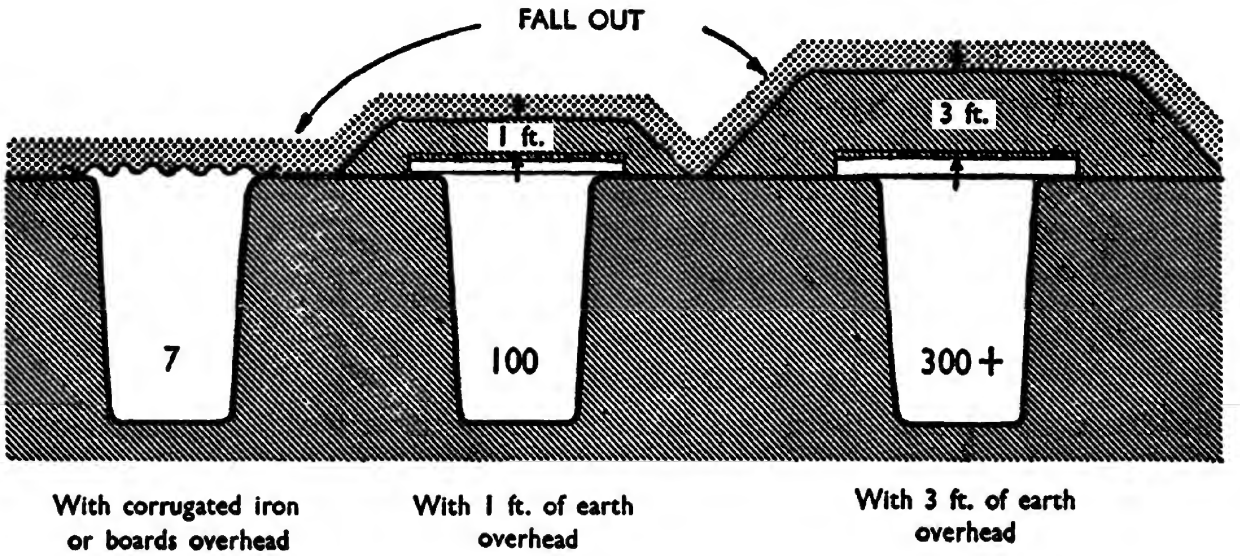


FIGURE 5

Protection factors in slit trenches (the factor by which the outside dose is divided to get the inside dose).

Choosing a refuge room

90 In choosing a refuge room in a house one would select a room with a minimum of outside walls and make every effort to improve the protection of such outside walls as there were. In particular the windows would have to be blocked up, e.g. with sandbags. Where possible, boxes of earth could be placed round an outside wall to provide additional protection, and heavy furniture (pianos, bookcases etc.) along the inside of the wall would also help. A cellar would be ideal. Where the ground floor of the house consists of boards and timber joists carried on sleeper walls it may be possible to combine the high protection of the slit trench with some of the comforts of the refuge room by constructing a trench under the floor.

Once a trap door had been cut in the floor boards and joists and the trench had been dug, there would be no further interference with the peace-time use of the room.

Estimated under-cover doses in the fall-out area

91 Taking an average protective factor of 40 for a two-storey house in a built-up area, the doses accumulated in 36 hours for the ranges referred to in the U.S. Atomic Energy Commission Report (paragraph 84) would have been:—

190 miles downwind		7½r
160 ,,	,,	12½r
140 ,,	,,	20r

15 Megatons
Bravo 1954

which are all well below the lowest figure of 25r referred to in Table 1. At closer ranges along the axis of the fall-out, the doses accumulated in 36 hours would have been much higher, but over most of the contaminated area—with this standard of protection—the majority of those affected would have been saved from death, and even from sickness, by taking cover continuously for the first 36 hours.

5. **Radiation sickness**

Assume dose incurred in a single shift (3–4 hours) by the "average" man, over the whole body:—

25 roentgens		—No obvious harm.
100 ,,		—Some nausea and vomiting.
500 ,,		—Lethal to about 50 per cent. people (death up to 6 weeks later).
800 ,,	or more	—Lethal to all (death up to 6 weeks later).

Note: If dose spread uniformly over 2–3 days, then 60 roentgens could be incurred with no more effect than 25 roentgens in a single exposure of 3–4 hours.

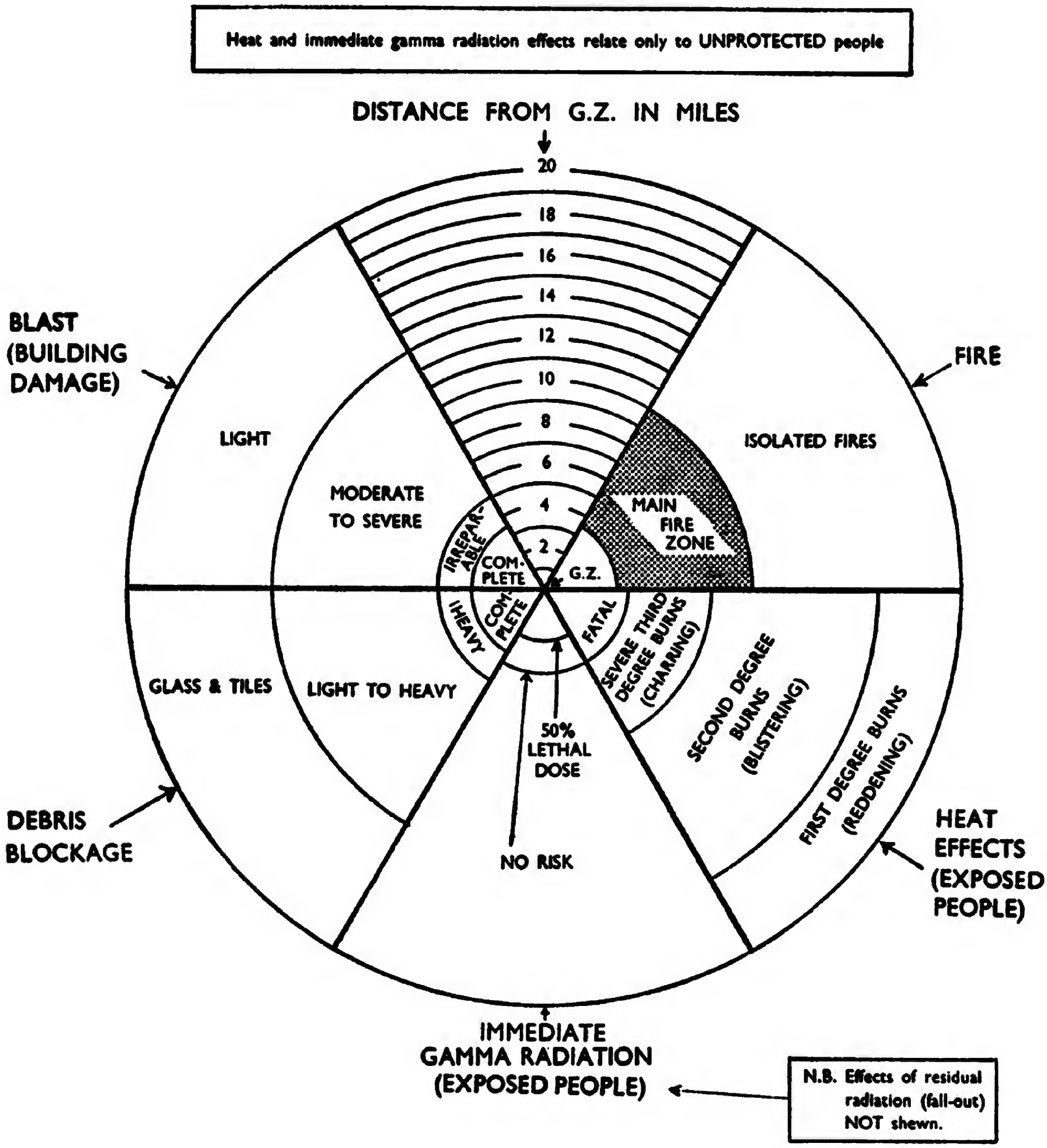


FIGURE 11

Combined effects (excluding residual radioactivity) from a 10 megaton ground burst bomb. Heat and immediate gamma radiation effects relate only to UNPROTECTED people.

A Fallout Forecasting Technique With Results Obtained at the Eniwetok Proving Ground

E. A. Schuert, USNRDL TR-139, United States Naval Radiological Defense Laboratory, San Francisco, Calif.

ADMINISTRATIVE INFORMATION

The work described herein is a part of the research sponsored by BuShips and the United States Army and locally designated as program 2, problem 3, phase 3. Its technical objective is AW-7 and it is described on RDB card NS 081-001.

SUMMARY

The problem: A fallout forecasting technique is needed to qualitatively describe the fallout hazard resulting from nuclear detonations. This technique should have such flexibility that its employment is valid for field use.

Findings: A summary of the latest experimental and theoretical considerations has resulted in the development of a technique whose complexity is dependent on the required accuracy of the results desired. This technique has been satisfactorily tested at the Eniwetok Proving Grounds for land surface and water surface bursts.

Particle size distribution in source model

All particle sizes were assumed at all elevations within the cloud except the lower two-thirds of the stem. However, to obtain agreement with past fallout measurements and with the optical diameter of the mushroom, it was necessary to fractionate the particle size distribution radially within the cloud. Otherwise, the computed fallout area about ground zero would be too large. The fractionation was specified as follows: particles of 1,000 microns in diameter and larger were restricted to the inner 10 percent of the mushroom radius or approximately the stem radius; those from 500 to 1,000 microns in diameter were limited to the inner 50 percent of the cloud radius. Since the relation of activity to particle size is some function of the particle diameter this fractionation tends to concentrate the activity about the axis of symmetry of the cloud.

Falling speeds **(feet/hour)**

J. M. Dallavalle, Mircomeritics, Pittman Publishing Corp., 1948.

Altitude	75 μ	100 μ	200 μ	350 μ	Altitude	75 μ	100 μ	200 μ	350 μ
0	3,060	5,040	11,700	21,600	65	4,190	7,480	26,100	51,100
5	3,120	5,240	12,300	22,900	70	4,110	7,320	27,600	55,200
10	3,200	5,480	12,900	24,100	75	4,010	7,150	28,100	59,700
15	3,270	5,750	13,700	25,500	80	3,910	6,960	27,800	61,900
20	3,360	5,980	14,400	27,100	85	3,800	6,770	27,100	67,800
25	3,470	6,160	15,300	28,800	90	3,720	6,640	26,500	71,300
30	3,570	6,380	16,300	30,800	95	3,620	6,470	25,800	77,300
35	3,720	6,640	17,500	33,000	100	3,550	6,340	25,300	80,200
40	3,870	6,910	18,600	35,300	105	3,470	6,180	24,800	75,800
45	4,040	7,200	19,800	37,800	110	3,400	6,050	24,000	74,200
50	4,210	7,520	21,400	40,600	115	3,330	5,930	23,700	72,600
55	4,420	7,860	23,200	44,600	120	3,260	5,800	23,400	71,100
60	4,200	7,700	24,400	47,200					

Experimental data from past tests at Eniwetok Atoll indicated that the particles were irregular in shape and had a mean density of 2.36 g/cu cm.

Time variation of the winds aloft

In most of the observations made at the Eniwetok Proving Ground, the winds aloft were not in a steady state. Significant changes in the winds aloft were observed in as short a period as 3 hours. This variability was probably due to the fact that proper firing conditions which required winds that would deposit the fallout north of the proving ground, occurred only during an unstable synoptic situation of rather short duration.

The forecasting technique described was employed by the fallout program at the Eniwetok Proving Ground to satisfy certain project requirements. One project had three ships equipped to collect fallout and their positions had to be determined for most efficient collection; another sampled the ocean for fallout; while another made an aerial survey of the contaminated area. The navigational schedules for these latter projects were based on the forecast fallout pattern. Operations were controlled through the program control center aboard the task force command ship where the forecasts were prepared.

The meteorological data was received from the weather ship at Bikini Atoll as well as from weather stations at Rongerik Atoll and Eniwetok Atoll. Furthermore all forecasts made by the task force weather central at Eniwetok Atoll were usually available aboard the command ship by facsimile through the ships weather station.

Upper air measurements were made at Bikini, Rongerik, and Eniwetok Atolls every 3 hours starting at H—24 hour and continuing until H+24 hour for any given detonation. The frequency of observations was usually increased during the period from H—6 to H—2 hours. The altitudes reached on the wind runs were remarkably high and gave perhaps the best set of winds-aloft measurements to date. The average termination altitude was approximately 90,000 feet with many runs over 100,000 feet. Such excellent coverage of the winds aloft was a major help in the fallout forecasting.

Fallout forecasts were made every 3 hours starting at H—24 hour using the *measured* winds available at the time. This process was continued up to shot time and from then on the technique of correcting for time variation was employed every 3 hours until the fallout event was completed. It was not feasible to correct for space variation and vertical motions during this period because of lack of time and data.

Fallout plots

The fallout forecasts determined at the weapons-test operation were based entirely on measured data and quantitatively considered time variation of the wind. No space variation corrections or computed values of vertical motions were employed in their construction.

A and B were land-surface detonations, C and D were water-surface shots.

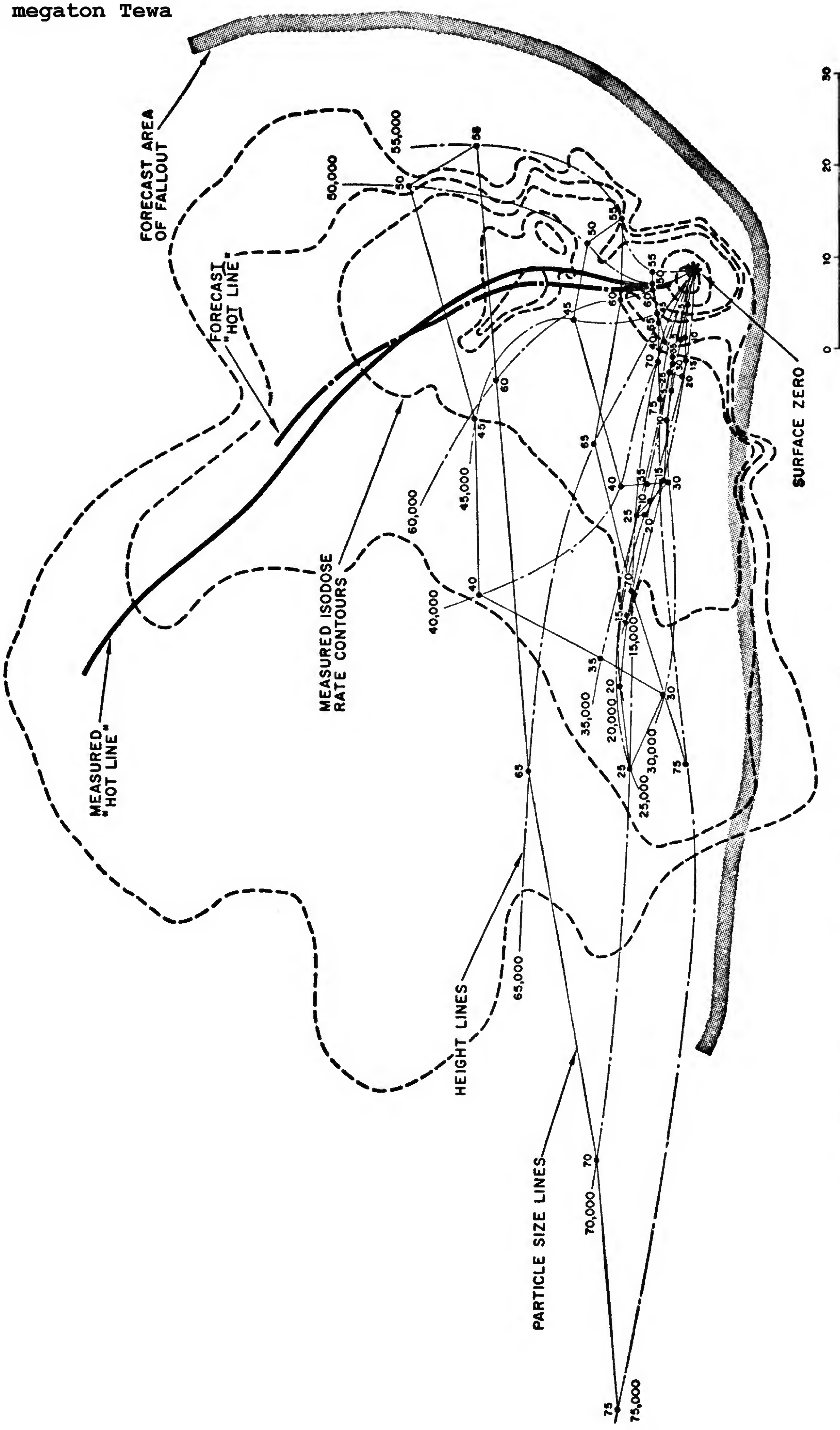
The comparison is excellent for all shots except B.

SUMMARY

The fallout forecasting technique described in this report was successfully employed for both land surface and water surface detonations at the Eniwetok Proving Ground. With known meterological data such a technique will successfully qualify the area of fallout and indicate qualitatively the relative intensity of radiation.

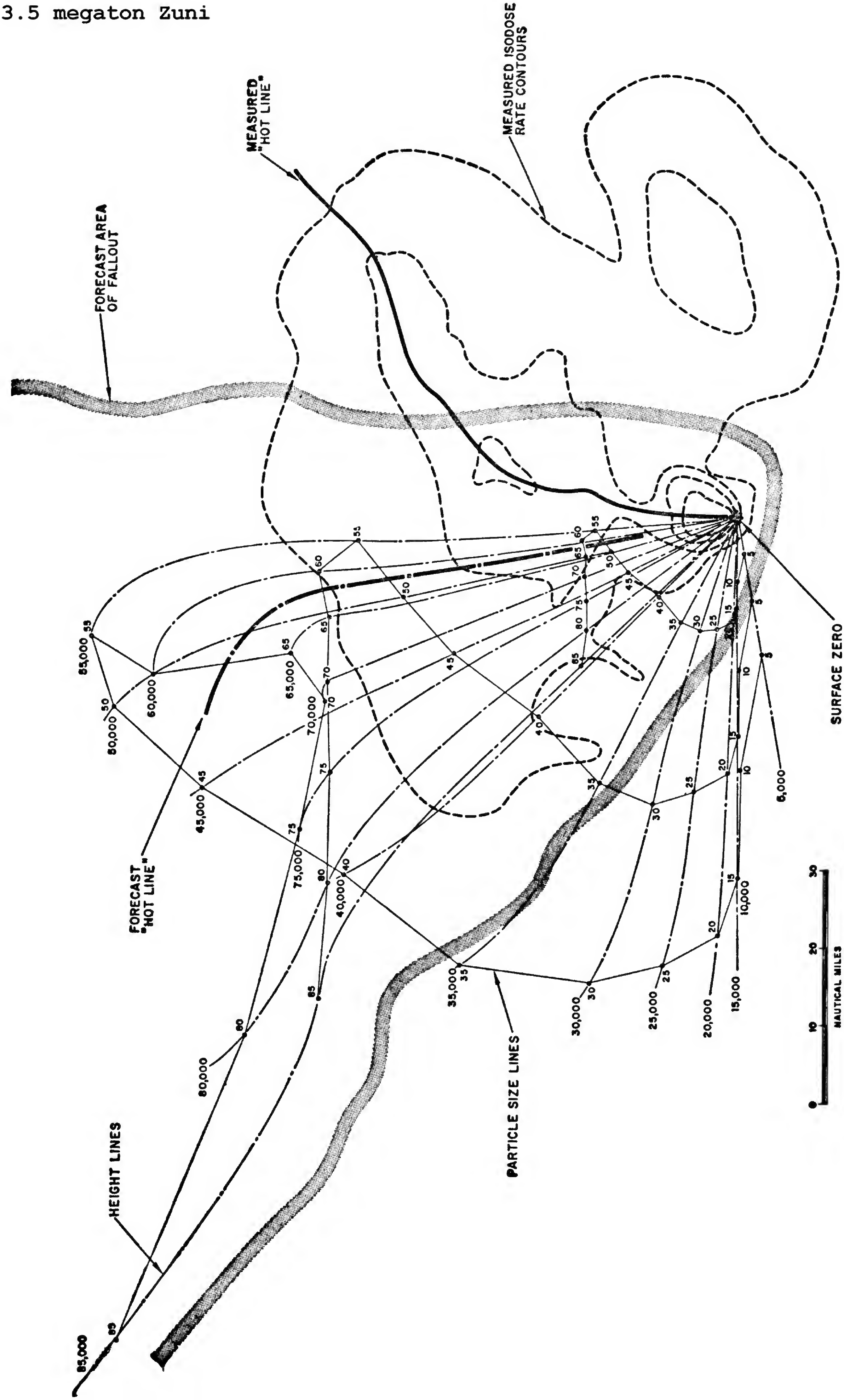
"Height lines" are deposit locations for all particles falling from a fixed altitude within the mushroom cloud. "Size lines" are deposit locations of a fixed particle size from various altitudes. A height line from the base of the mushroom disc is the "hot line".

5 megaton Tewa



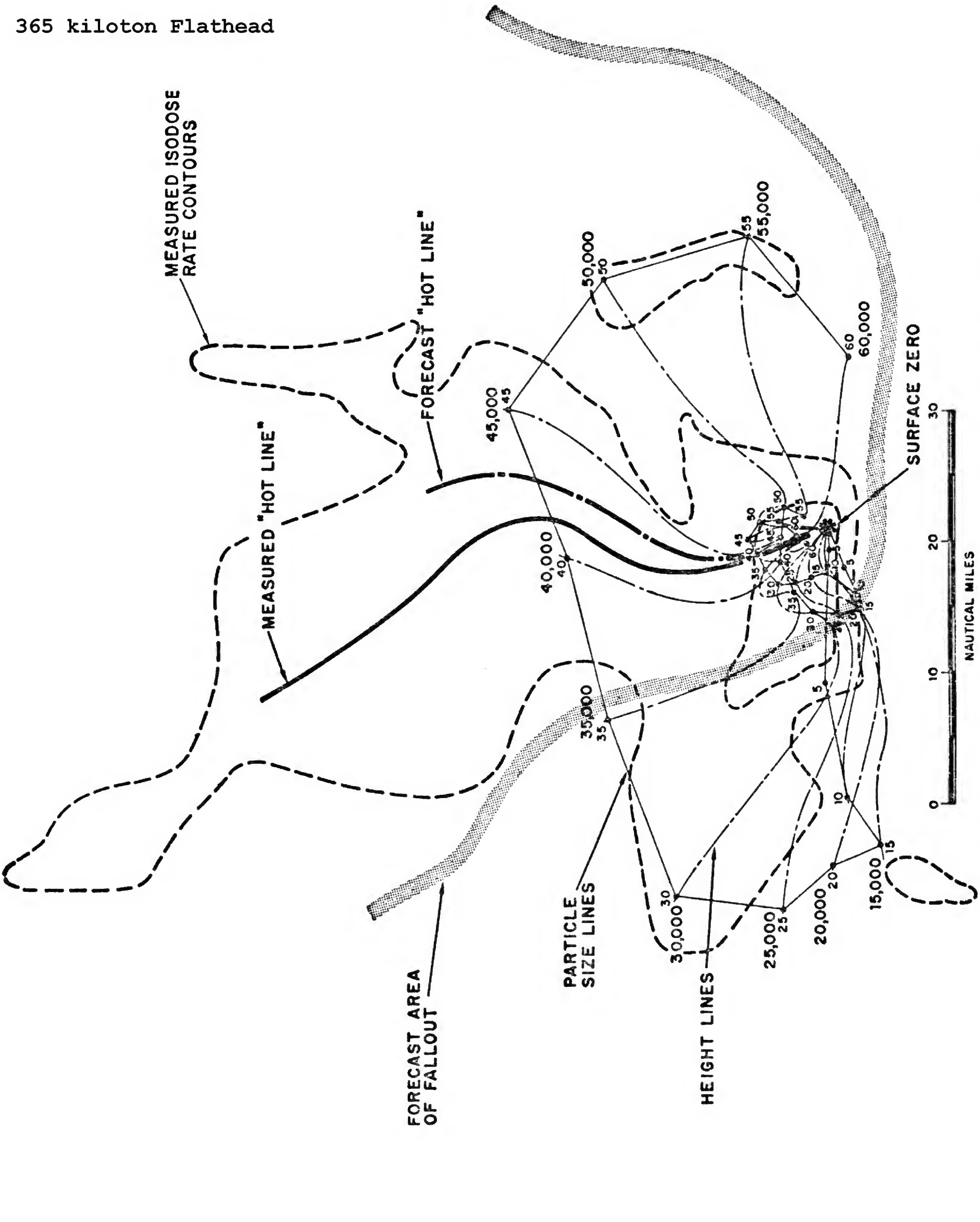
Comparison of fallout forecast with test results—shot A

3.5 megaton Zuni



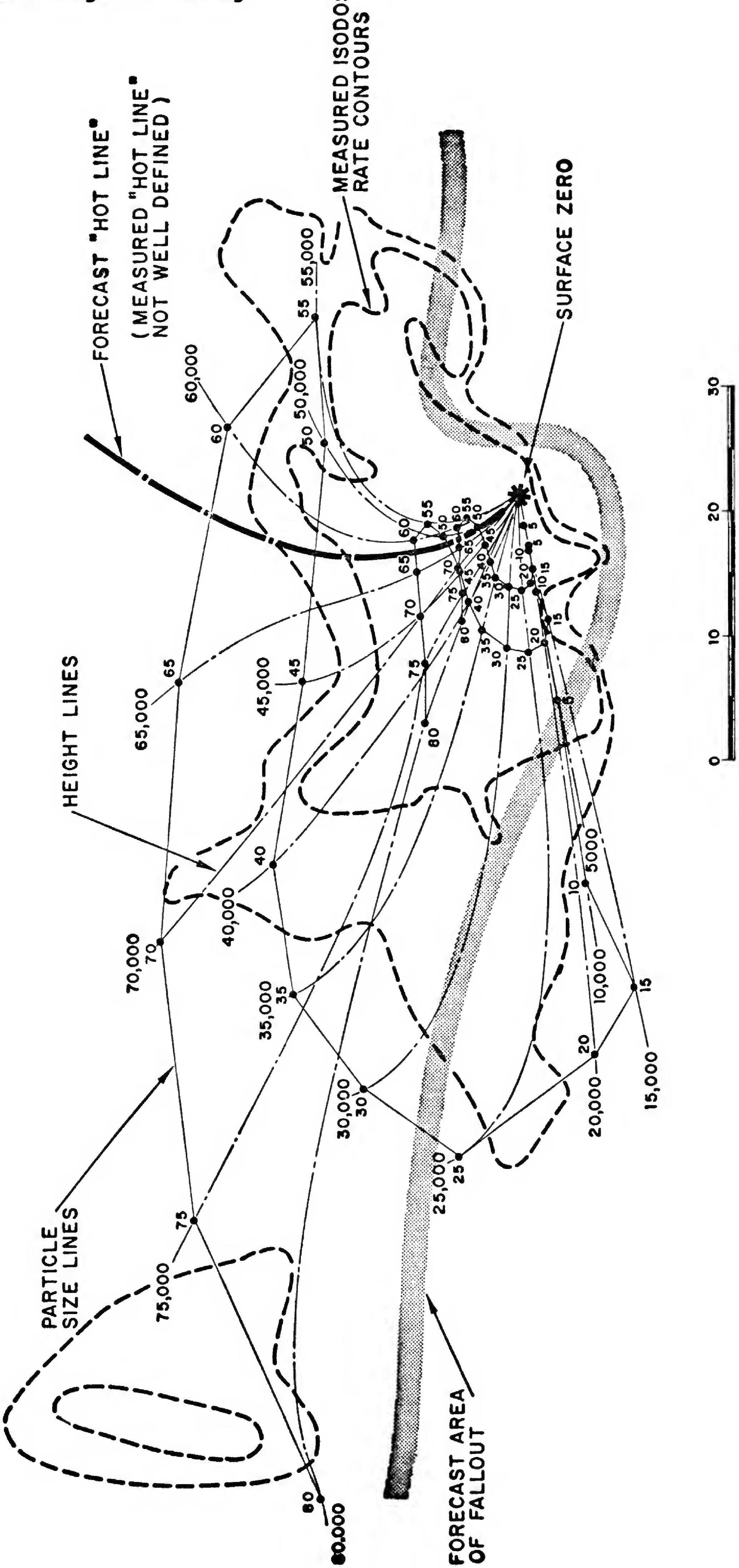
Comparison of fallout forecast with test results—shot B.

365 kiloton Flathead



Comparison of fallout forecast with test results—shot C.

4.5 megaton Navajo



Comparison of fallout forecast with test results—shot D.

SECRET

WT-615

This document consists of 84 pages
No. 254 of 265 copies, Series A

Report to the Scientific Director

NATURE, INTENSITY, AND DISTRIBUTION OF FALL-OUT FROM MIKE SHOT

(The first 10 megaton H-bomb test, 1952)

By

W. B. Heidt, Jr., LCDR, USN
E. A. Schuert
W. W. Perkins
R. L. Stetson

U. S. Naval Radiological Defense Laboratory
San Francisco, California

April 1953

RESTRICTED DATA

This document contains restricted data as defined in the Atomic Energy Act of 1946. Its transmittal or the disclosure of its contents in any manner to an unauthorized person is prohibited.

SECRET
SECURITY INFORMATION

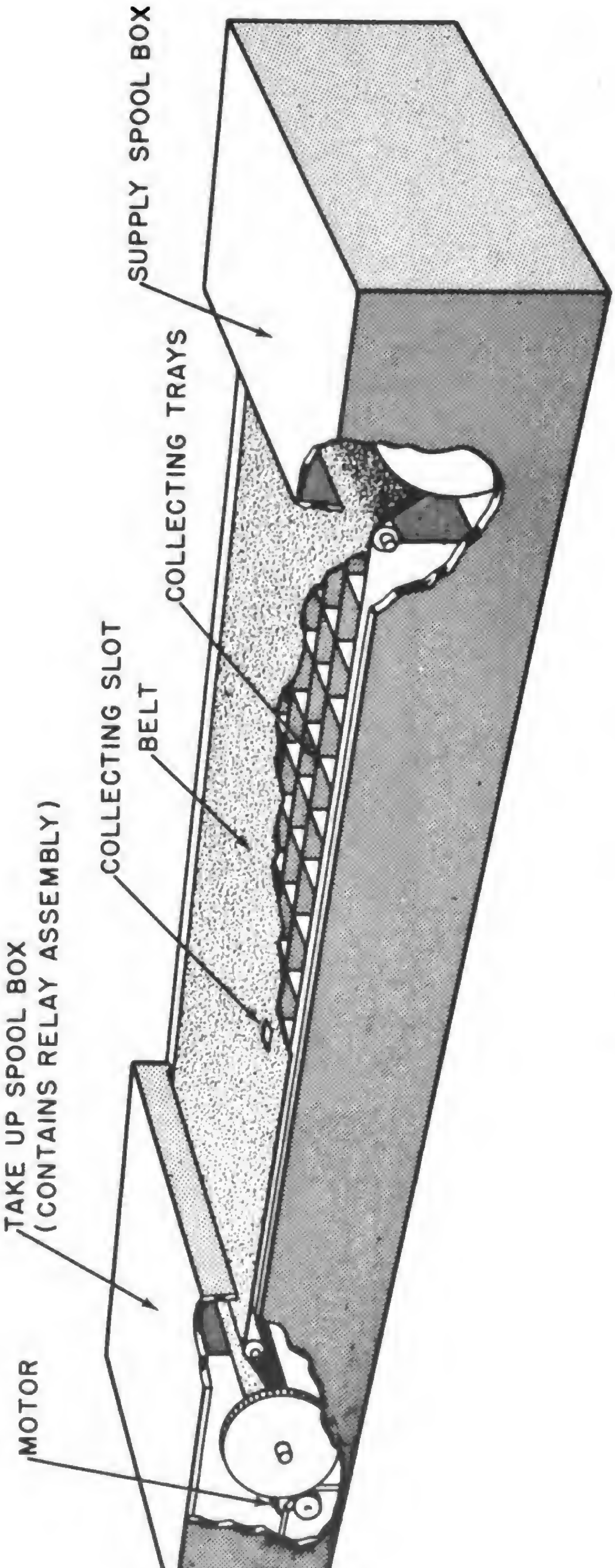


Fig. 3.2—Differential fall-out collector.

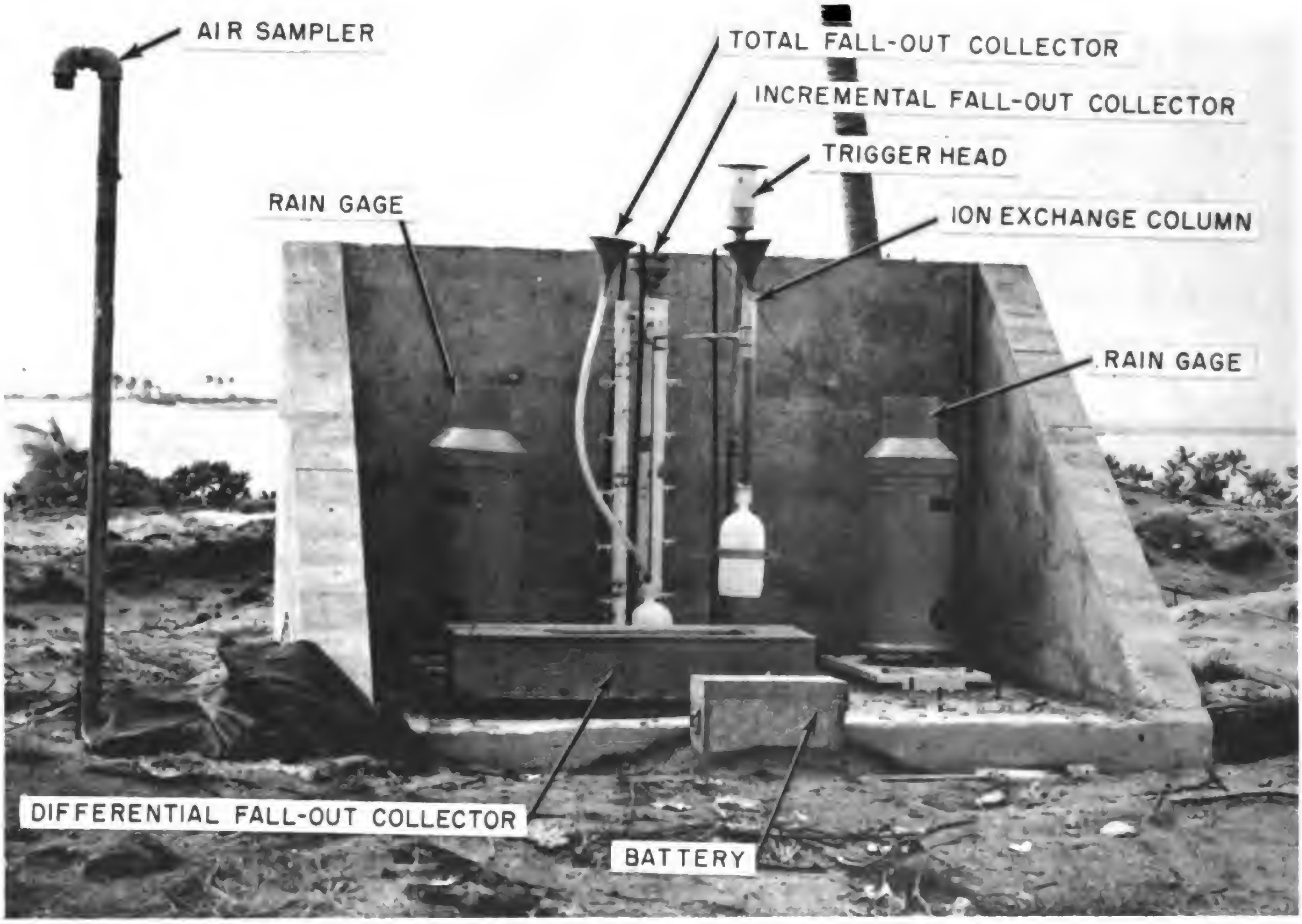


Fig. 3.8—A typical land station.

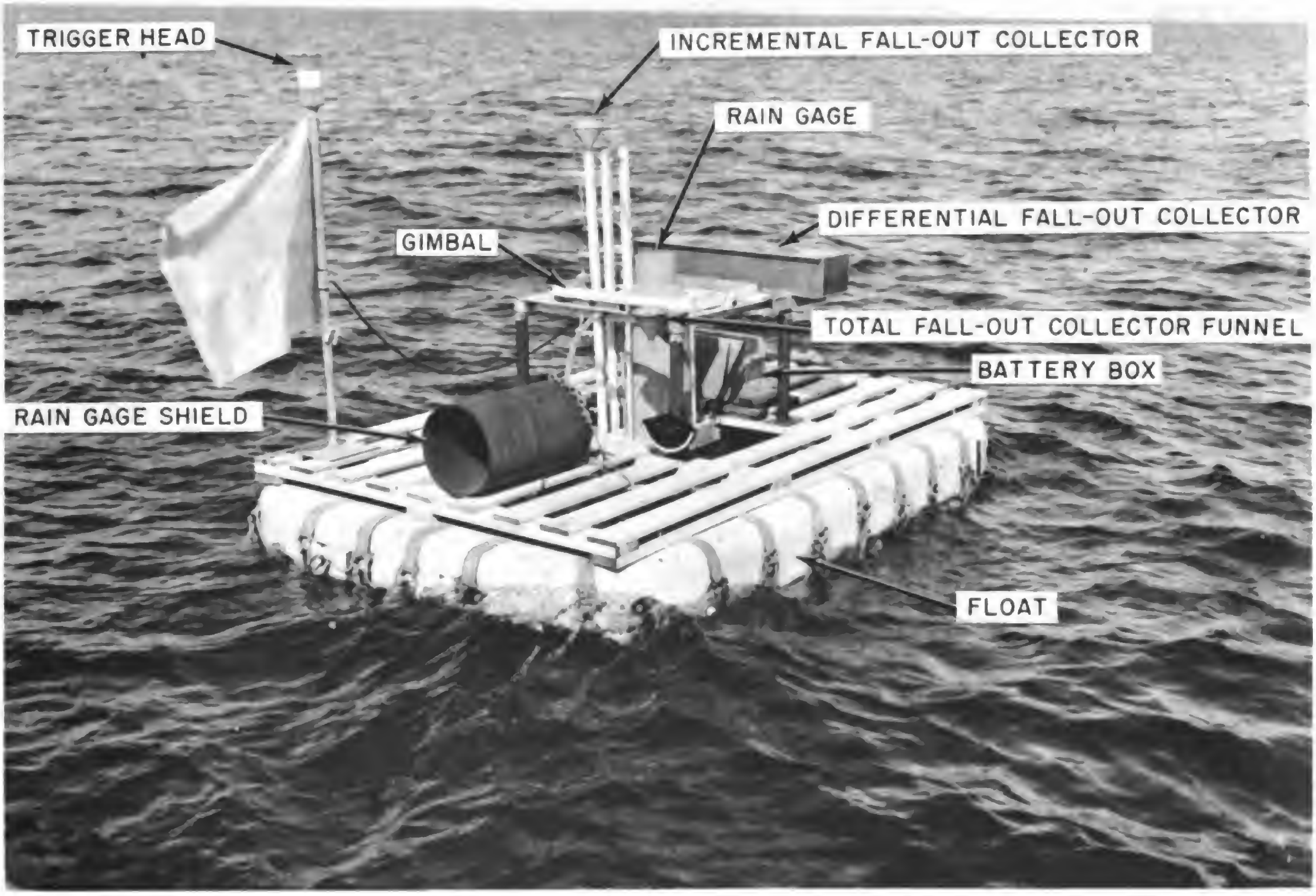


Fig. 3.9—A typical lagoon station.

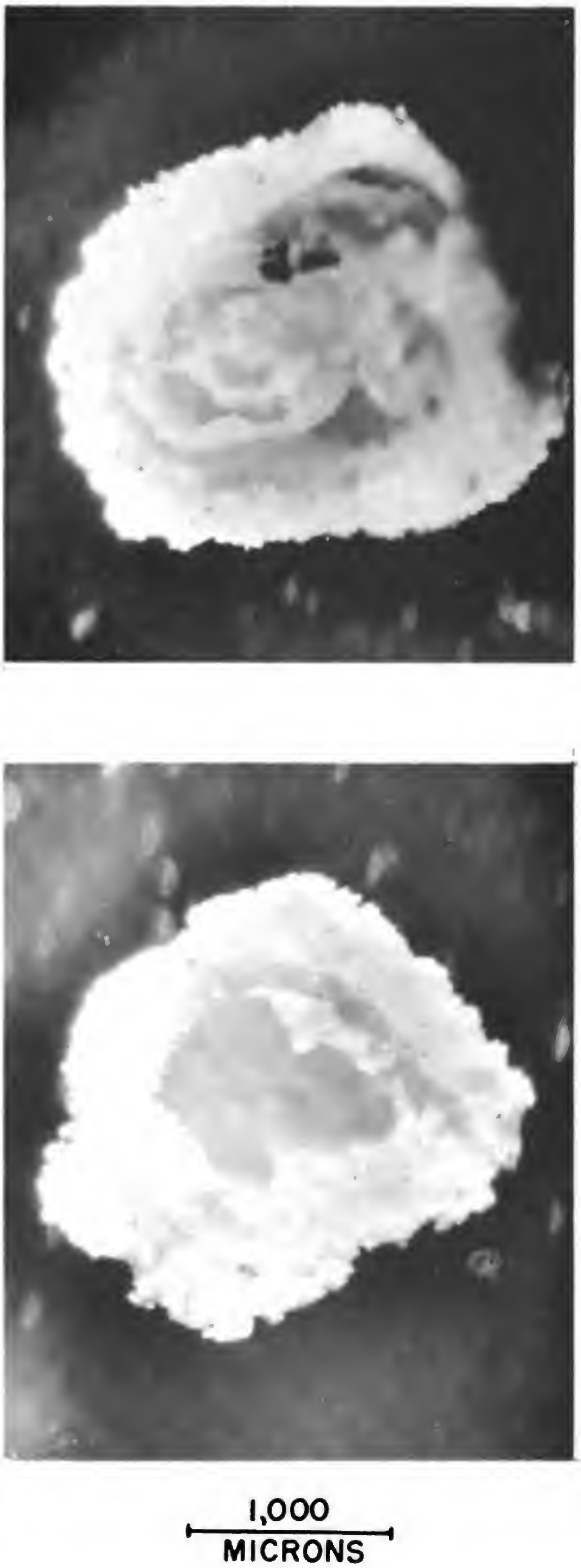


Fig. 4.4—Inverted view of typical particles removed from life-float decking.

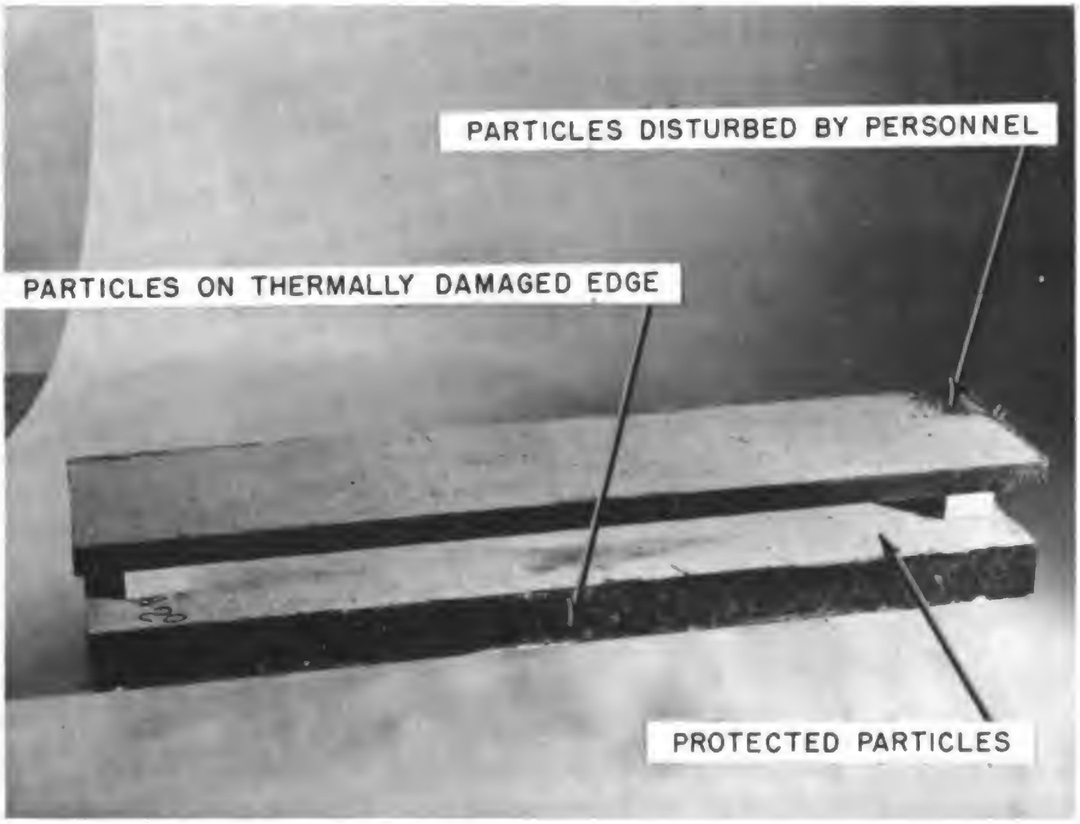


Fig. 4.5—Typical life-float section.

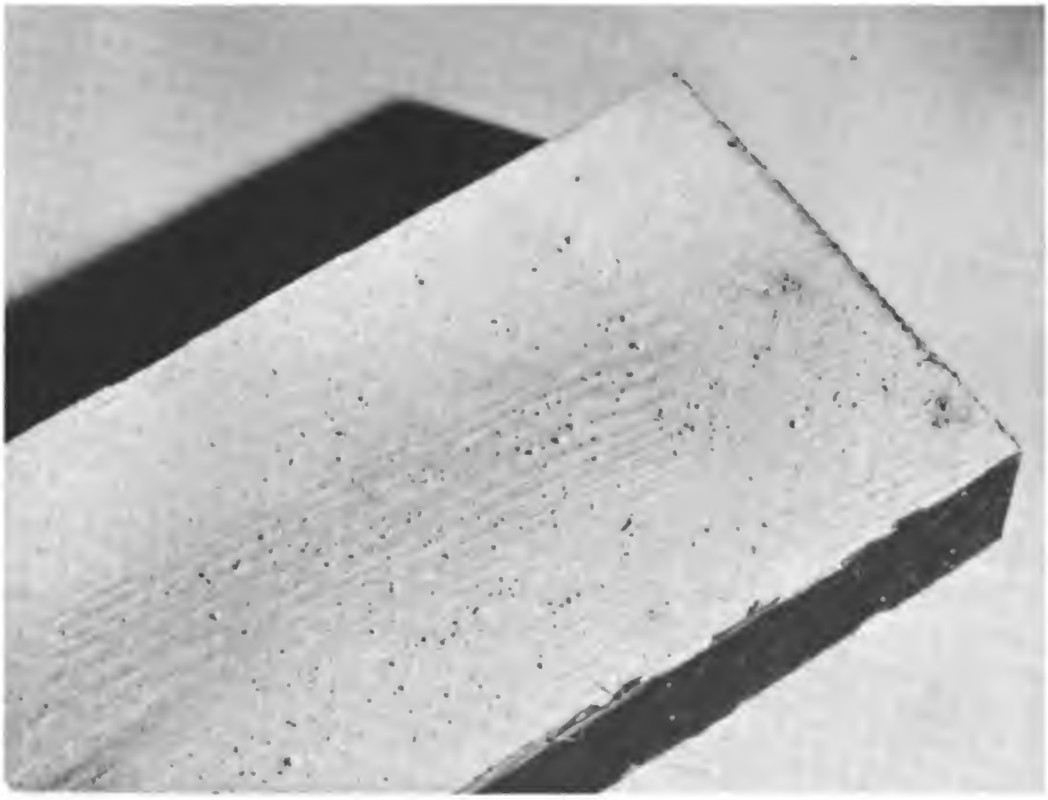


Fig. 4.6—Particle deposition on life-float decking (lower deck of Fig. 4.5).

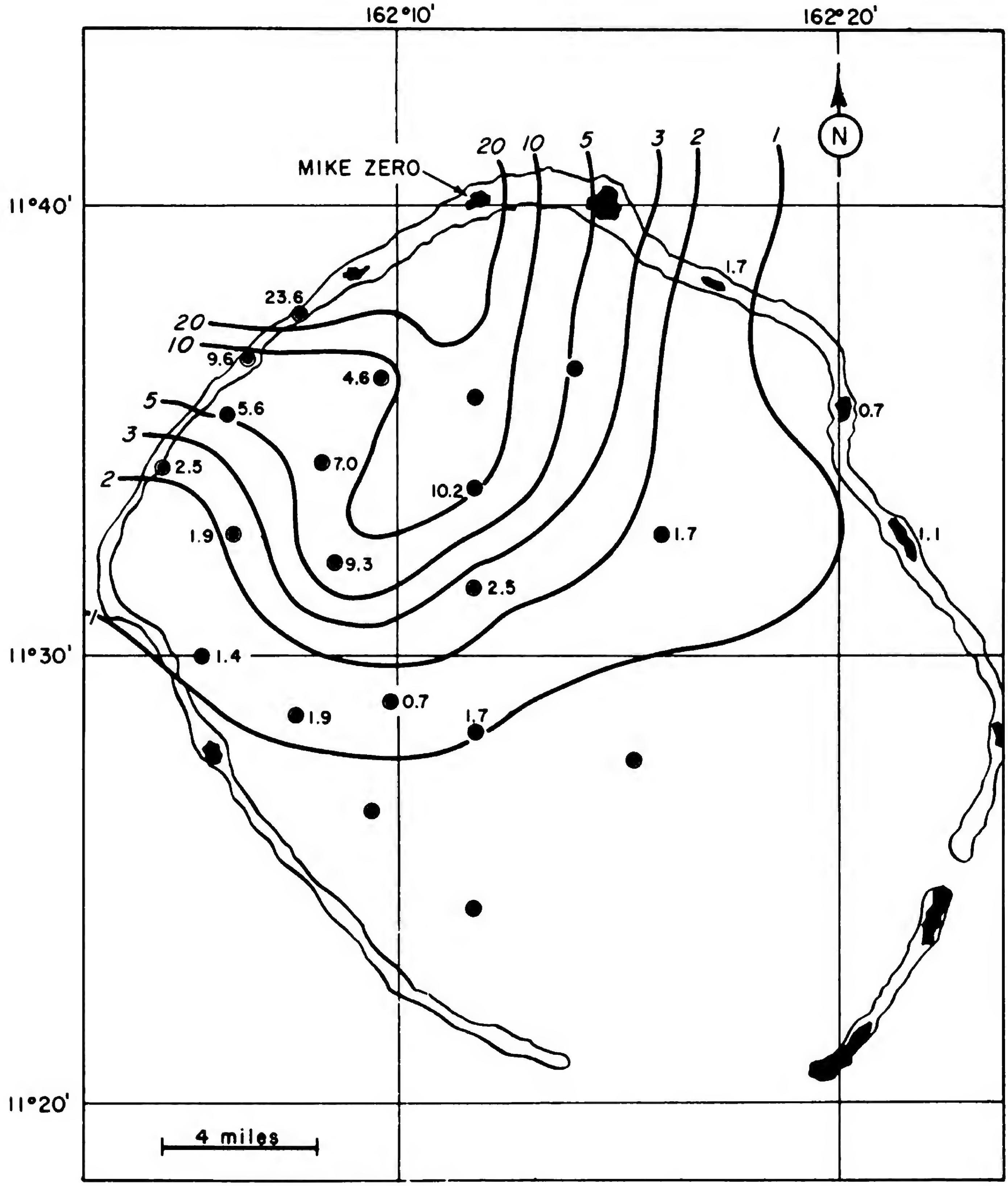


Fig. 4.8—Mass distribution of fall-out (g/sq ft).

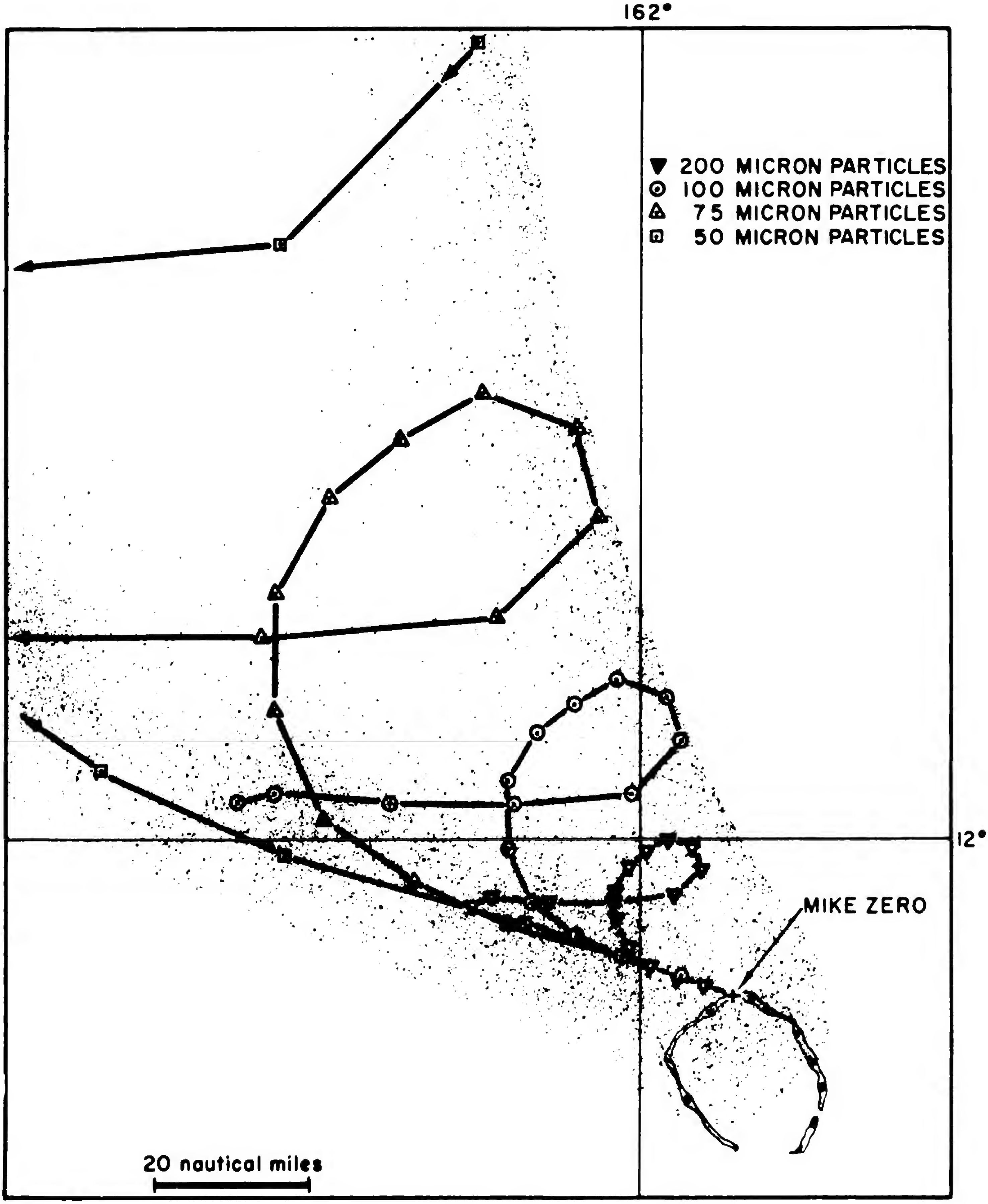


Fig. 6.1—Predicted area of primary fall-out.

WT-915

This document consists of 172 pages

No. 238 of 240 copies, Series A

OPERATION CASTLE

Project 2.5a

DISTRIBUTION AND INTENSITY OF FALLOUT

REPORT TO THE SCIENTIFIC DIRECTOR

by

R. L. Steton
E. A. Schuert
W. W. Perkins
T. H. Shirasawa
H. K. Chan

This document regraded
From SECRET
To UNCLASSIFIED
Date 14 July 82
Authority DNA LTR 6/14/82

(The Castle-Bravo 15 megaton H-bomb test of 1 March 1954, which contaminated a Japanese tuna trawler and islanders)

January 1956

[redacted]

[redacted]

U. S. Naval Radiological Defense Laboratory
San Francisco 24, California

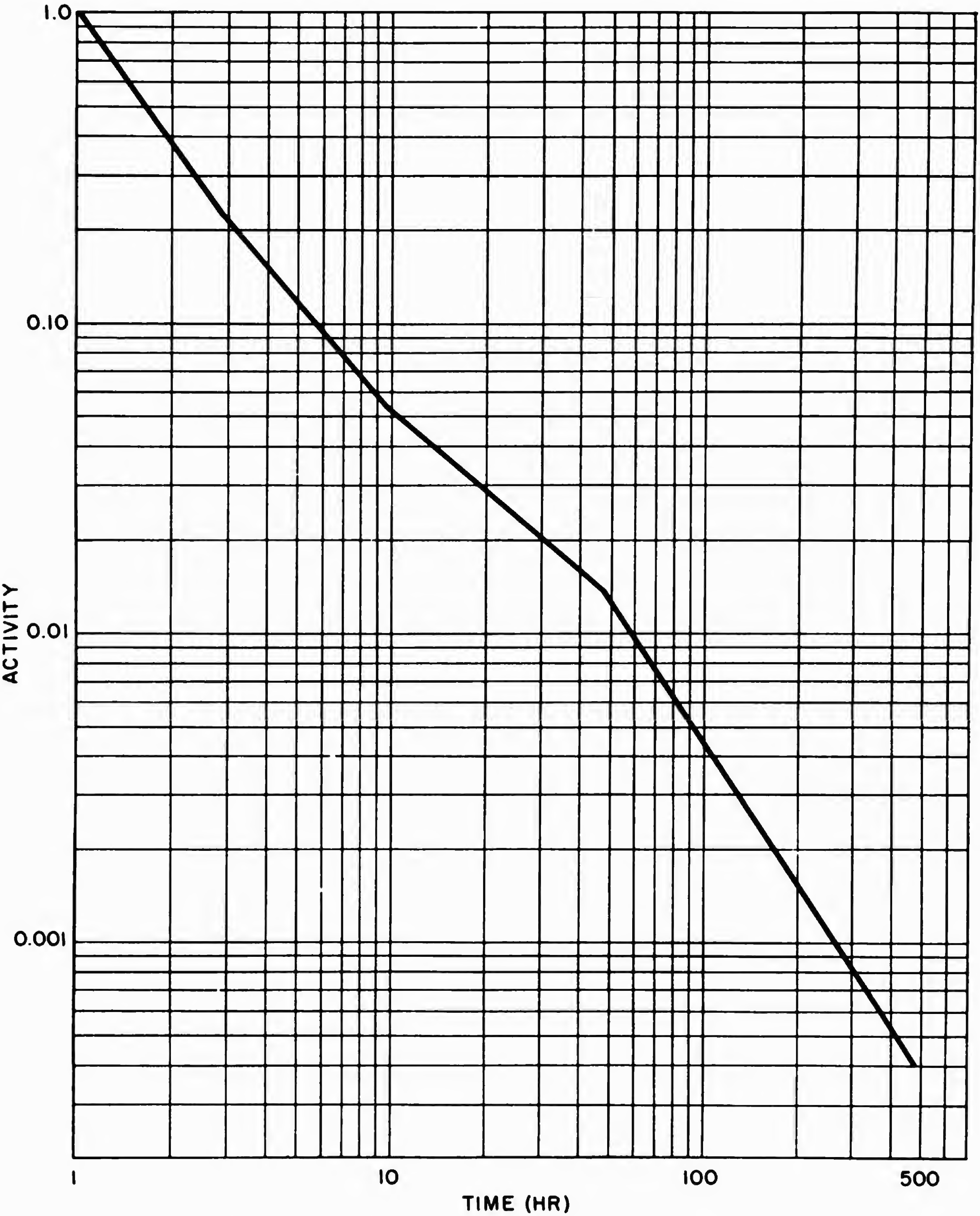


Fig. 5.3 Composite Gamma Ionization Decay Curve

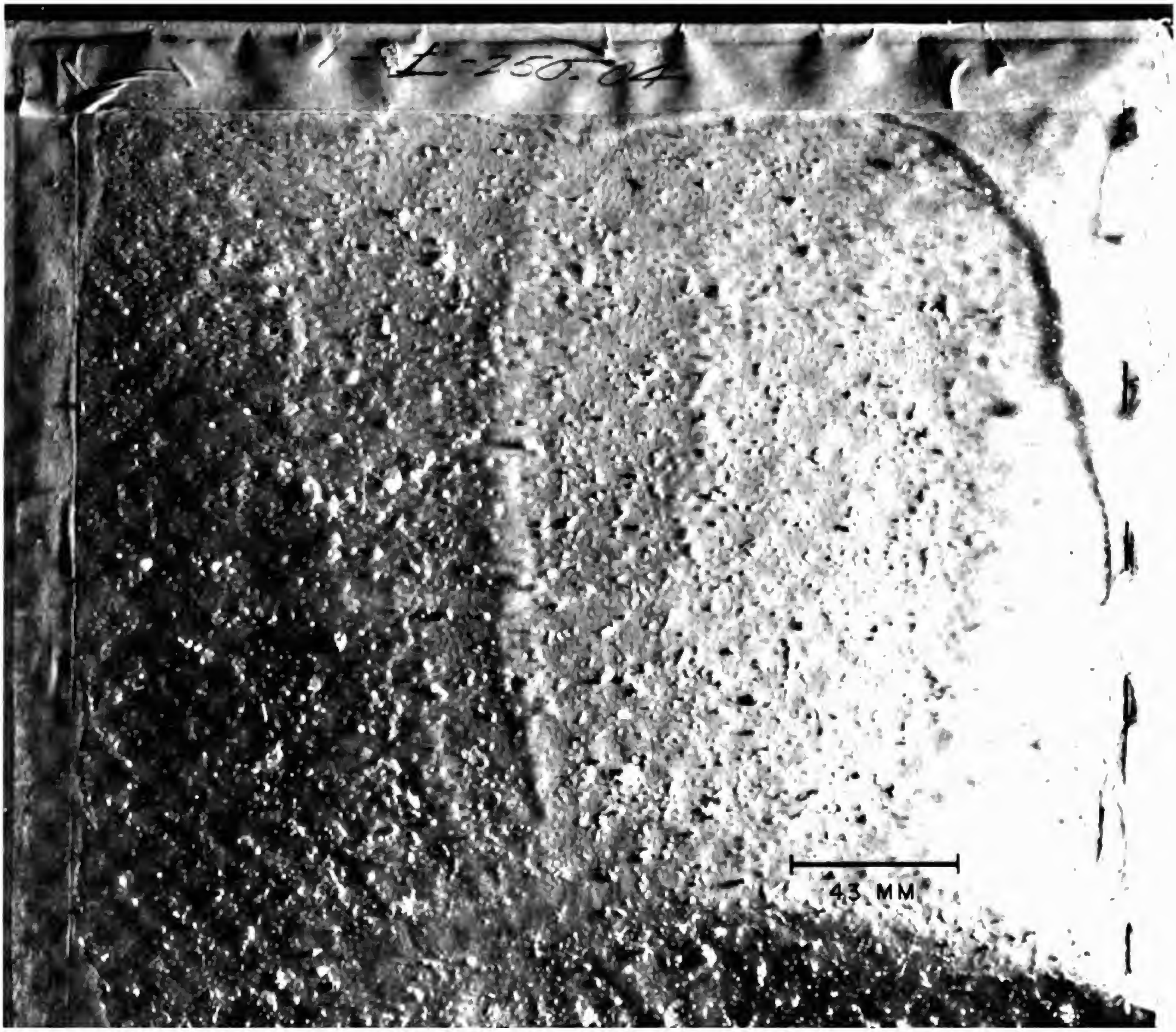


Fig. 5.10 Shot 1, Fallout Particulate, Station 250.04

This is a raft downwind in Bikini Lagoon, which received a land equivalent of 113 R/hr (1 hour reference gamma dose rate), according to Figures 2.2 and 6.1. Land equivalent dose rates were 7 times the raft dose rate in the lagoon.

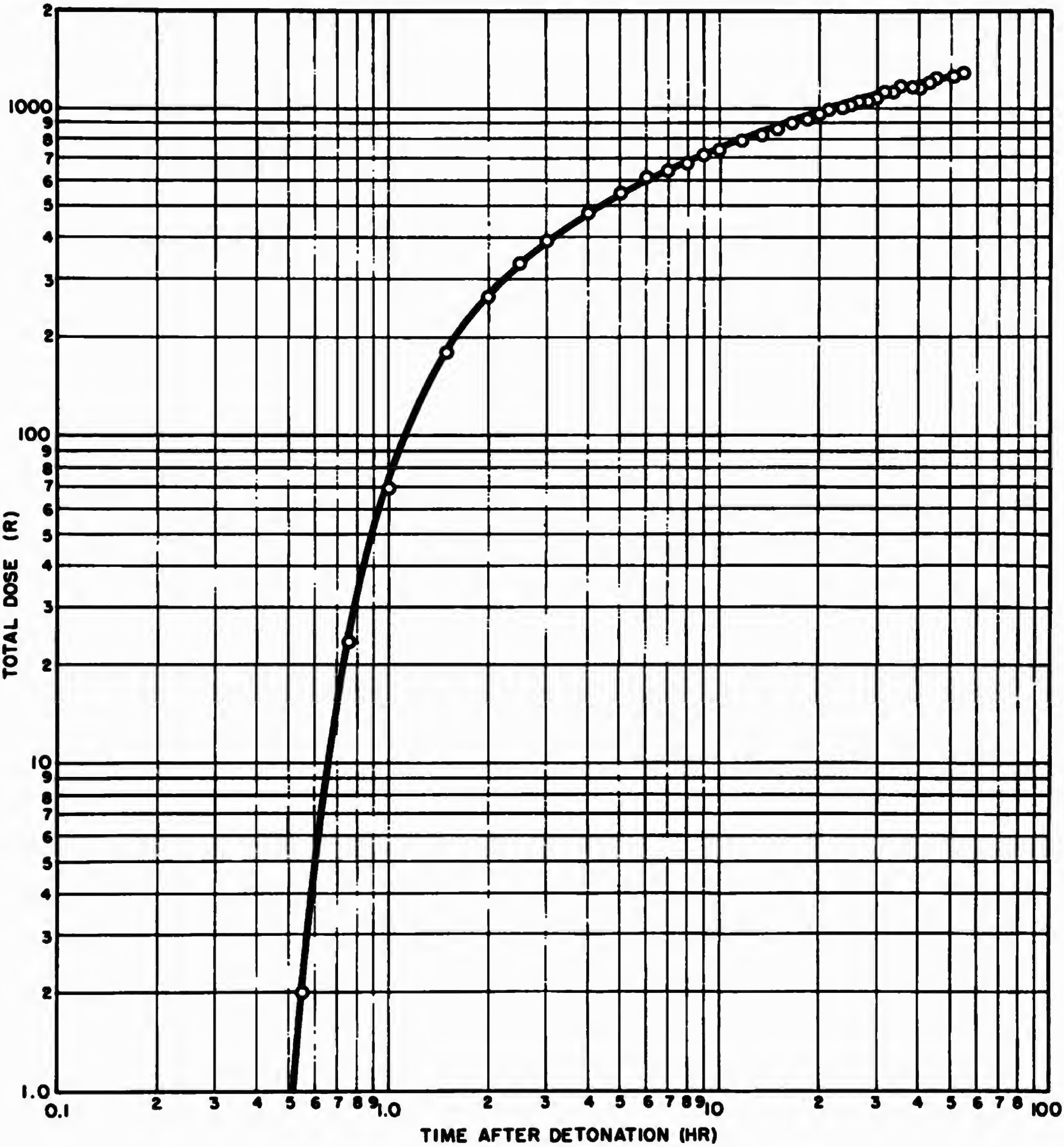


Fig. 5.11 Shot 1, Integrated Gamma Dose, Station 251.03

Bikini (How) Island in Bikini Atoll, which received a land equivalent of about 725 R/hr gamma at 1 hour reference time, according to Figures 2.2 and 6.1.

[redacted]

UNCLASSIFIED

SANITIZED VERSION

TECHNICAL ANALYSIS REPORT - AFSWP NO. 507-SAN

RADIOACTIVE FALL-OUT HAZARDS FROM SURFACE BURSTS OF VERY HIGH YIELD NUCLEAR WEAPONS, Sanitized Version

by

D. C. Borg
L. D. Gates
T. A. Gibson, Jr.
R. W. Paine, Jr.

WEAPONS EFFECTS DIVISION

This Armed Forces Special Weapons Project Technical Analysis Report is a staff study prepared for the Chief, AFSWP on a subject of military interest. The conclusions may be modified as new data become available.

MAY 1954

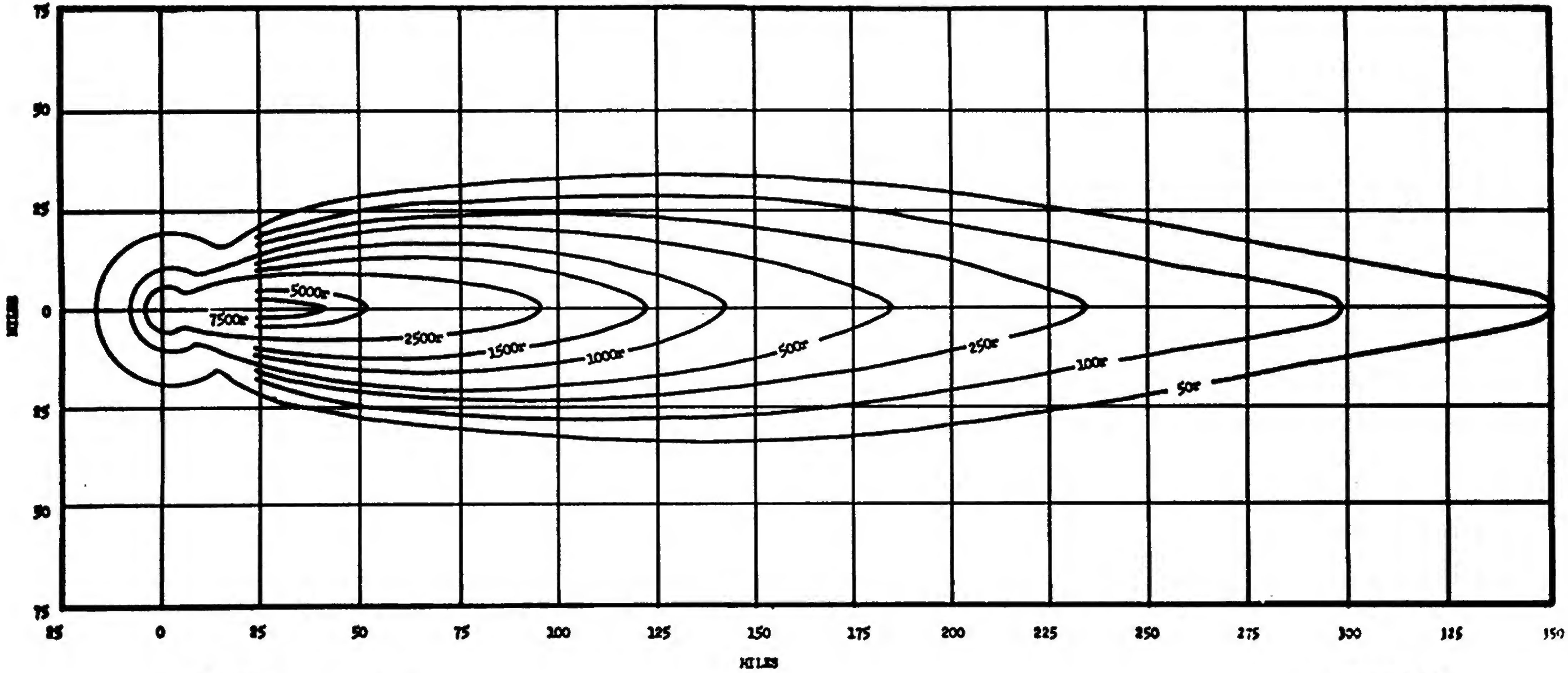
HEADQUARTERS, ARMED FORCES SPECIAL WEAPONS PROJECT
WASHINGTON 13, D. C.

[redacted]

[redacted]

Fig. A TOTAL DOSE FROM TIME OF FALL OUT TO H+50

Idealized Fall-out Contours for a 15 MT Land-surface Burst with a 15 Knot Effective Wind



[redacted]

[redacted]

The shielding afforded by an ordinary frame house may effectively reduce the size of the hazard areas by a factor of about two, and a basement shelter by a factor of ten or more. Virtually complete protection against the lethal effects of radioactive fall-out can be obtained if personnel have protection equal to or better than that afforded by a simple underground shelter with at least three feet of earth cover, and if they are evacuated after a week or ten days in such a shelter.

One may draw the following conclusions from this analysis:

a. Very large areas, of the order of 5,000 square miles or more, are likely to be contaminated by the detonation of a 15 megaton yield weapon on land surface, in such intensities as to be hazardous to human life.

b. The fact that a large percentage of the radiologically hazardous area will lie outside the range of destructive bomb effects for normal wind conditions, extending up to several hundred miles downwind, makes the radiological fall-out hazard a primary anti-personnel effect.

c. Accurate pre-shot prediction of the location of the hazardous area with respect to the burst point is virtually impossible without extensive wind data at altitudes up to about 100,000 feet, owing to the sensitive wind-dependence of the distribution mechanism.

d. The fall-out contaminant can be expected to decay at such a rate that all but the most highly contaminated areas could be occupied by previously unexposed personnel on a calculated risk

basis within a few days after the contaminating event; and even these highly contaminated areas may then be entered briefly by decontamination teams.

e. Passive defense measures, intelligently applied, can drastically reduce the lethally hazardous areas. A course of action involving the seeking of optimum shelter, followed by evacuation of the contaminated area after a week or ten days, appears to offer the best chance of survival. At the distant downwind areas, as much as 5 to 10 hours after detonation time may be available to take shelter before fall-out commences.

f. Universal use of a simply constructed deep underground shelter, a subway tunnel, or the sub-basement of a large building could eliminate the lethal hazard due to external radiation from fall-out completely, if followed by evacuation from the area when ambient radiation intensities have decayed to levels which will permit this to be done safely.

g. It is of vital importance for individuals in hazardous areas to seek optimum shelter at once, since the dosage received in the first few hours after fall-out has commenced will exceed that received over the rest of a week spent in the contaminated area.

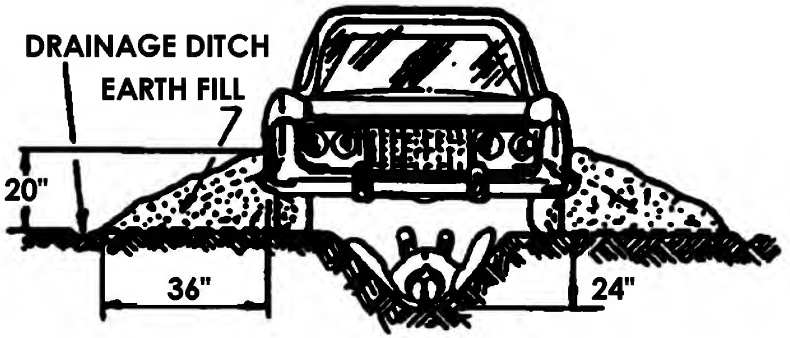
Table II

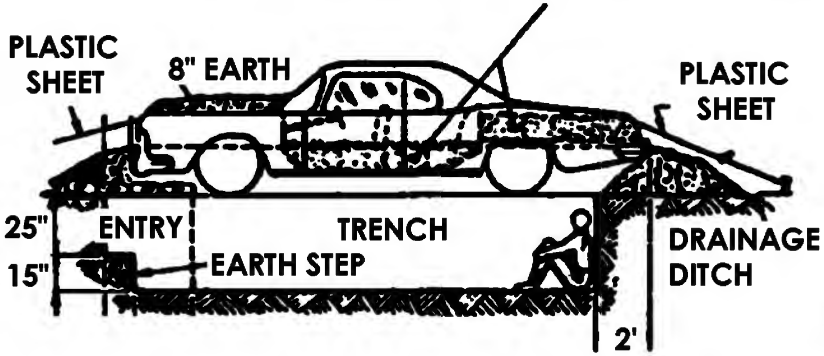
Total Isodose Contour: 500r from Fall-out to H+50 Hours

Yield (MT)	15	1	10	60	* 60
Downwind extent (mi)	180	52	152	340	(307)
Crosswind axis (mi)	40	12	34	70	
GZ circle radius (mi)	11.5	3.85	9.7	21	
GZ circle displacement (mi)	3.5	1.2	3	5.75	
Area (mi^2)	5400	470	3880	17,900	(16,250)
Area of true ellipse (mi^2)	(5650)	(491)	(4055)	(18,700)	

* Using Part D, Chapter II.

CAR-OVER-TRENCH FALLOUT SHELTER (EXPEDIENT SHELTER HANDBOOK)





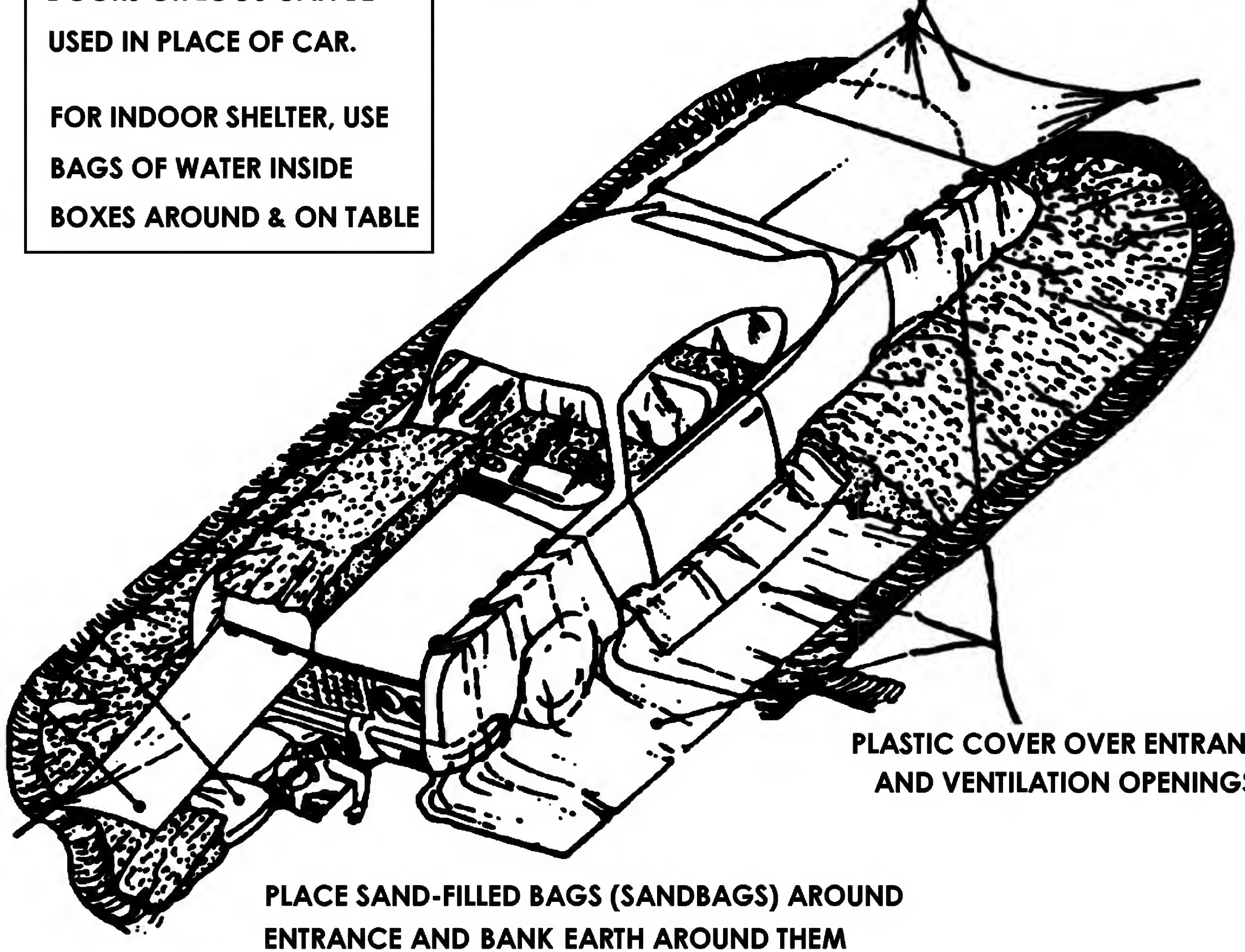
BANK EXCAVATED EARTH 20 INCHES HIGH AROUND CAR

PLACE 8" OF EARTH ON CAR HOOD

DIG SHALLOW DRAINAGE DITCH AROUND FILL

DOORS OR LOGS CAN BE USED IN PLACE OF CAR.

FOR INDOOR SHELTER, USE BAGS OF WATER INSIDE BOXES AROUND & ON TABLE

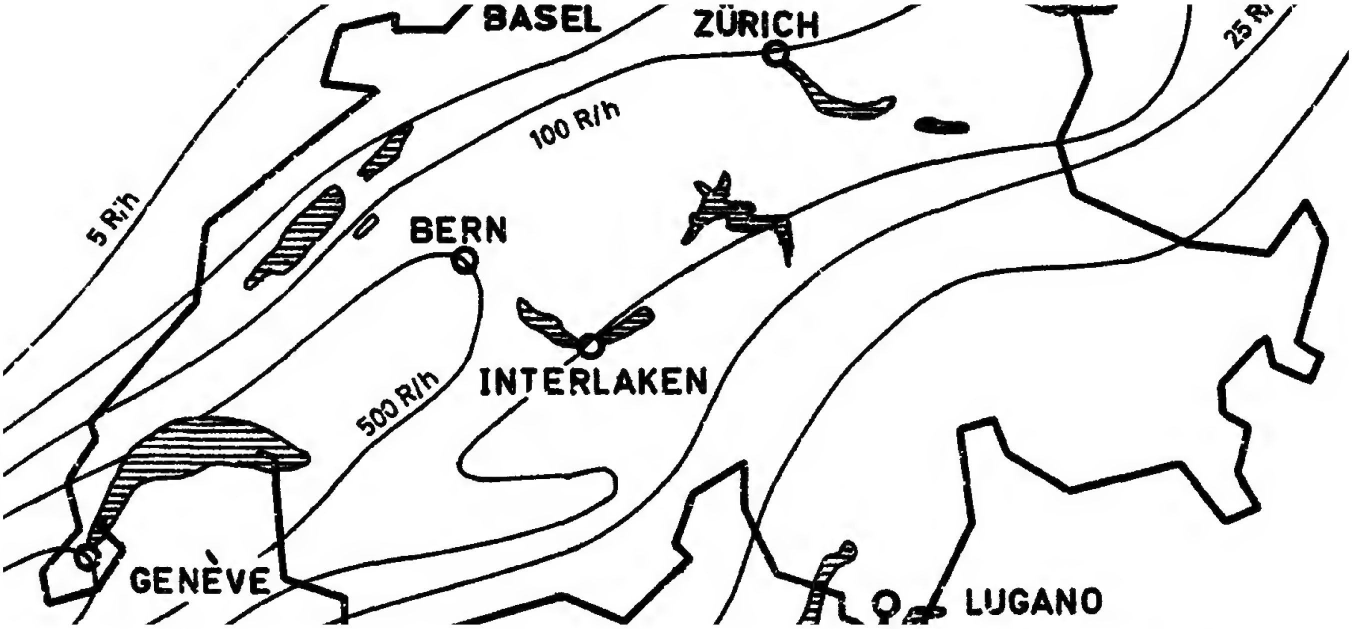


FACHVERBAND FÜR STRAHLENSCHUTZ E.V.

Mitgliedsgesellschaft der International Radiation Protection Association (IRPA)

PROCEEDINGS of a SYMPOSIUM

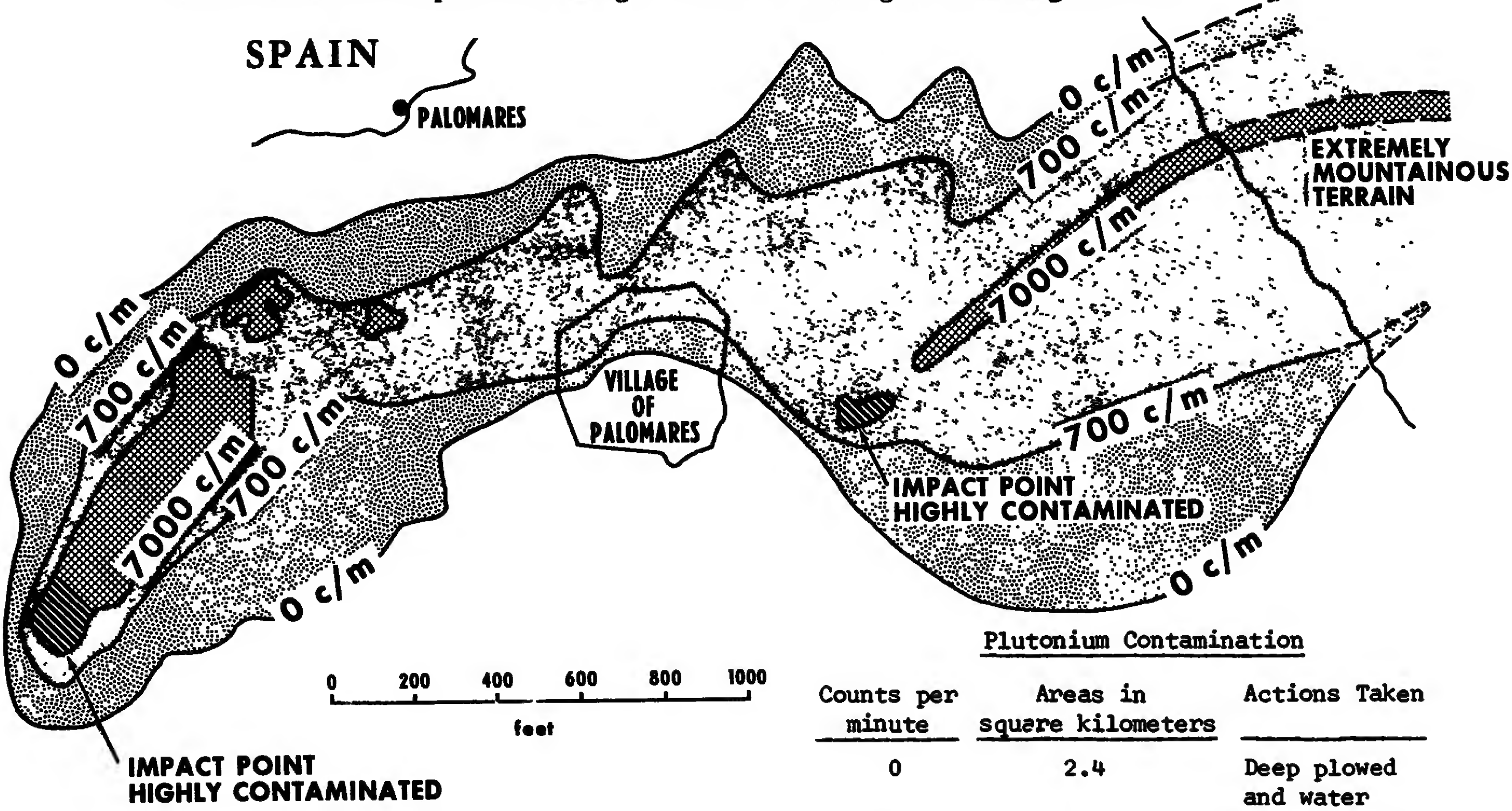
RADIOLOGICAL PROTECTION OF THE PUBLIC IN A NUCLEAR MASS DISASTER



Front row: O. Burkhardt, Administrative Secr. of the Symposium - S. Prêtre, Pres. of "Fachverband für Strahlenschutz" - Dr. C.F. Miller, URS Corp., Burlingame, California - Bundesrat L. von Moos, Member of the Swiss Government, Minister of Justice and Police - W. König, Dir. of the Swiss Federal Office of Civil Defense - Prof. E.P. Wigner, Princeton Univ., Nobel Prize in Physics 1963 - H. Brunner, Scientific Secr. of the Symposium.

INTERLAKEN, SWITZERLAND, 26 MAY–1 JUNE 1968

On January 17, 1966, a B-52 U.S. Air Force aircraft with nuclear bombs aboard crashed in Spain following an accident during a refueling mission.



Plutonium Contamination

Counts per minute	Areas in square kilometers	Actions Taken
0	2.4	Deep plowed and water
700	2.0	(Deep plowed,
7,000	0.17	(watered and (vegetation removed
over 60,000	0.022	Surface scraped

Plutonium quickly oxidizes forming insoluble plutonium oxide.

The potential sources of inhalation of plutonium under these conditions are one, the cloud of radioactive material as it rolls by immediately after the event and, two, resuspension of the plutonium from the ground into the air afterwards. Available data indicate that the first source will probably result in a higher amount of plutonium being deposited in the lungs.[1.]

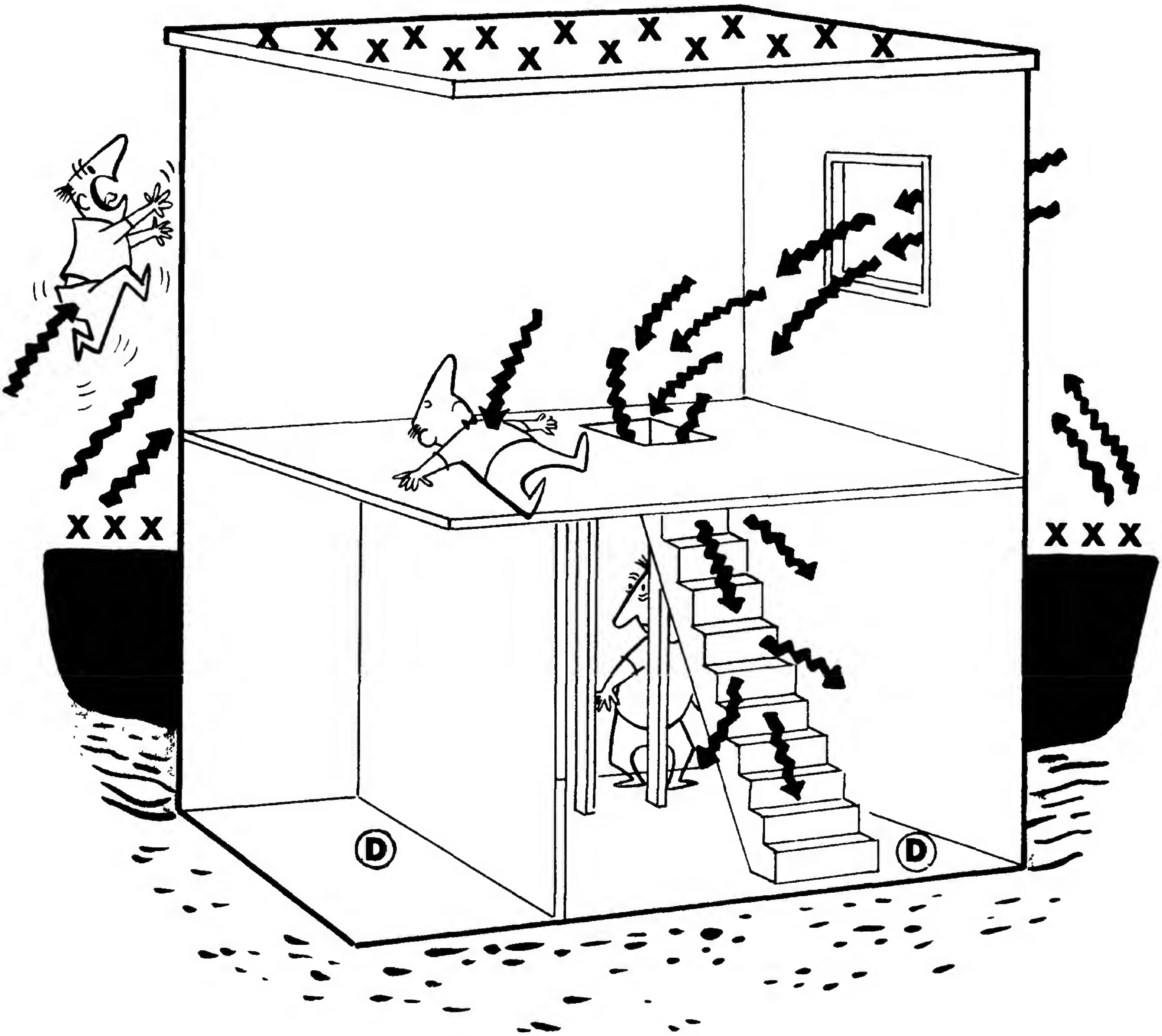
In short, experiments[1., 2.] showed that if a person were exposed to the highest concentration of plutonium in the cloud from such an accident he might receive a total radiation dose to the lungs of about 5 to 10 rem. The second of the major field tests was conducted under inversion meteorological conditions in order to maximize the concentration in the air at ground level.

1. Summary Report, Test Group 57; Report No. ITR-515 (Del.), Shreve, J.D., Jr. April 1958.
2. Operation Roller Coaster 1963. "Biological Studies Associated with a Release of Plutonium." Wilson, Robert and Terry, Jack.

STATUS OF FALLOUT SHIELDING CALCULATIONS IN THE USA

C. Eisenhauer, NBS

In summary, there is a continuing program of experimentation going on to check the accuracy of the present calculations used to predict protection from fallout. However, this program must be accompanied by another which studies the impact of inaccuracies on the various phases of the Civil Defense program. It is not unlikely that there is a range of protection factors for which much greater accuracy is required.



THE NATURE AND BEHAVIOR OF LOCAL FALLOUT

By

Carl F. Miller

THE FORMATION PROCESS

The larger glassy particles, formed from vaporized and melted soil material, are entrained in the fireball before it cools to the melting point of the soil. During this time, the larger melted particles not only collide and coalesce with the smaller liquid soil droplets, but serve as a condensation media for other vaporized condensable fission products. The crystalline particles, entering the fireball after it has cooled to temperatures less than the melting point of the soil material, collect only late-condensing fission product radionuclides on their surfaces in addition to intercepting a few of the small vapor-condensed particles. The late-condensing fission products consist mainly of the volatile elements such as Sb, Te, and I, and the daughter products of rare gases such as Rb and Cs.

The derived specific activity of the local fallout from Shot SMALL BOY, a low-yield device detonated near ground surface at the Nevada Test Site, is shown as a function of particle diameter in Figure 1. The low values of the specific activity for the smaller particles resulted from the unavoidable presence of extraneous local dust particles in the collected samples.

The curve of Figure 1 may be represented by:

$$C = \frac{3.5 \times 10^{18}\left[1 - e^{-6.9 \times 10^{-4} d}\right]}{d}, \quad d = 50 \text{ to } 4{,}000 \text{ microns} \qquad (1)$$

where d is the particle diameter in microns and C is in fissions per gram. The range in d indicates that essentially all of the radioactive particles falling in the local fallout area were greater than 50 microns and that essentially none were found larger than 4,000 microns. The form of Equation 1 and the numerical coefficient values indicate that the gross radionuclide content of the particles is essentially proportional to particle volume or weight for particles with diameters between about 50 and 200 microns. For particles with larger diameters, the radionuclide content becomes increasingly concentrated on the surface of the particles and at diameters of about 2000 microns and larger, the radionuclide content is essentially proportional to

surface area (i.e., to 1/d). The specific activity of the smaller particles would be expected to be larger than the limiting value of Equation 1 and should increase somewhat as the diameter decreases below about 50 microns.

The major significance of the two-stage fallout formation process, aside from the resulting bimodal particle type composition, is that the radionuclides that condense into the liquid droplets in the first stage become immobilized with regard to latter contamination of water and cycling in food chains; but the radionuclides that condense in the second stage on the surfaces of the particles may not be permanently immobilized and do become involved in later biochemical processes.

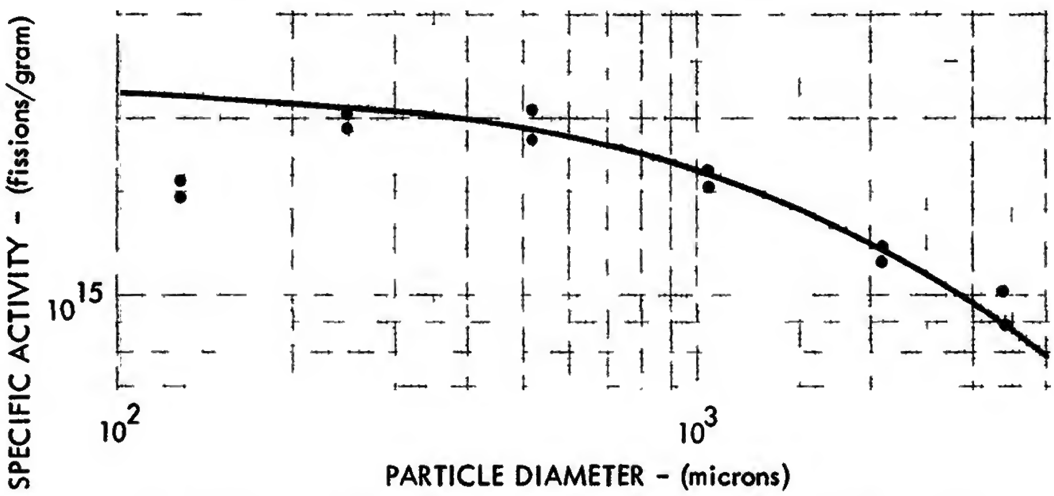


Figure 1. Specific Activity For Shot Small Boy.

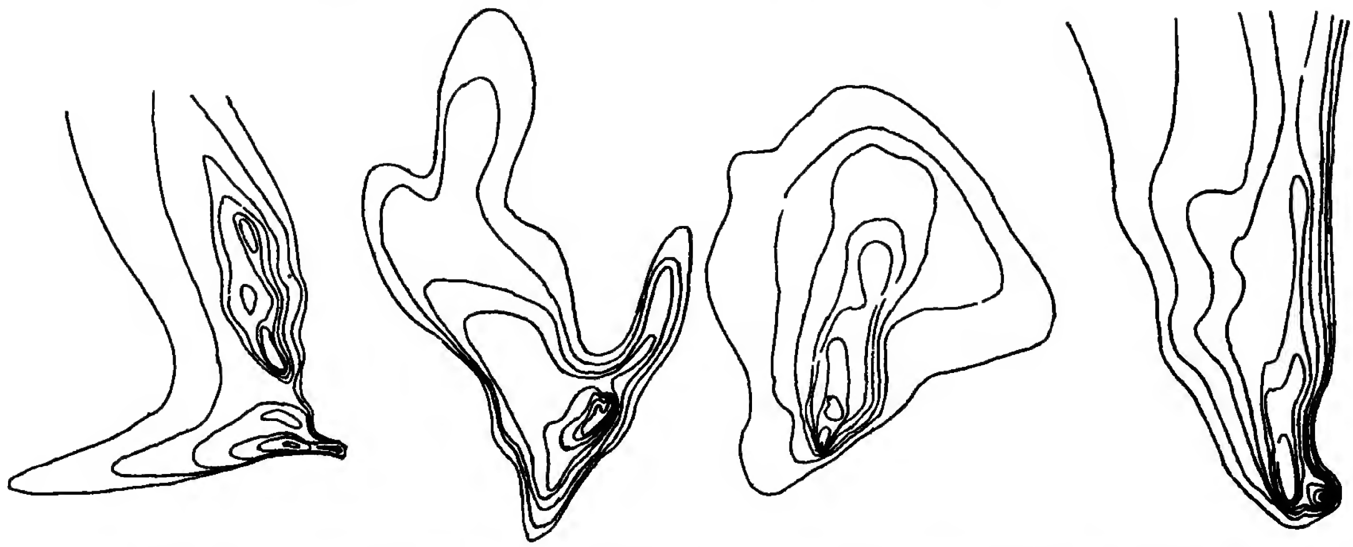


Figure 2. Example Representations of Observed Fallout Patterns.

As the fireball cools and rises into the atmosphere, toroidal circulations take place. This circulation apparently concentrates the remaining gaseous radionuclides and smaller particles in the center of the toroid and, due to the downward flow of air at the periphery, accelerates the falling out of the larger particles. Thus, the time of arrival of the largest fallout particles is usually less than is estimated on the basis of free fall from the bottom of the cloud.

BETA RADIATION HAZARDS AND BETA-GAMMA RELATIONSHIPS ASSOCIATED WITH LOCAL FALLOUT

J. D. Teresi*

U. S. Naval Radiological Defense Laboratory
San Francisco, California 94135

Four cases of beta-ray burns of the hands, which occurred during an atomic bomb test at Eniwetok, have been reported by Knowlton et.al.[2] Two of the men received beta ray doses of 5,000 - 10,000 rads, another received 8,000 - 16,000 rads, and the fourth received 3,000 - 4,500 rads. For all but the smallest dose, skin damage was so extensive that grafts were required. There was loss of mobility of some of the fingers. In one case serious ulcers persisted for periods greater than 100 days after the exposure. The effects of the smallest dose were less pronounced; however, the damage persisted for a period greater than 50 days.

Amount of Transepidermal Radiation Required for the Production of Recognizable Transepidermal Injury (Porcine Skin) From Ref. (1)

Isotope	Maximum Beta Energy (Mev)	Surface Dose Required (rep)	Estimated Dose at 0.09-mm Depth (rep)
S-35	0.17	20,000	1200
Y-91	1.53	1,500	1200

2000-4000 rad	Early erythema under 24 hours Skin breakdown in 2 weeks
4000-10,000 rad	Severe erythema in 24 hours Severe skin breakdown in 1-2 weeks
10,000-30,000 rad	Severe erythema in 4 hours Severe skin breakdown in 1-2 weeks
30,000-100,000 rad	Immediate skin blistering (less than 1 day)

The expected beta dose rate at contact in a large field contaminated by fallout was calculated[10] to be 40 times the gamma exposure-rate reading taken at 3 feet. For example if the gamma reading at 3 feet is 100 R/hr, the expected beta dose rate at contact will be 4,000 rads/hr. This is true for a beta-particle to gamma-photon ratio of 1. This ratio is approximately equal to unity for times after a nuclear burst of a few hours to 3 or 4 months. At early times (a few minutes to an hour) the ratio may be as high as 2, in which case the beta dose rate will be 80 times the gamma exposure rate.

The beta doses associated with local fallout contamination of terrain and clothing have also been estimated by Pretre[11] who compared the beta and gamma doses to people exposed to terrain and clothing contaminated with fallout. His calculations were essentially in agreement with those reported in reference 10.

REFERENCES

1. Moritz, A.R., and Henriques, F.W., "Effects of Beta Rays on Skin as a Function of Energy, Intensity and Duration of Exposure. II - Animal Experiments", Lab. Invest. 1, No. 2, 167, 1952.

2. Knowlton, N.P., Leifer, E., Hogness, J.R., Hempelmann, L.H., Blaney, L.F., Gill, D.C., Oakes, W.R., and Shafer, C.C., "Beta Ray Burns of Human Skin", J.A.M.A., 141, 239, 1949.

10. Broido, A., and Teresi, J.D., "Analysis of the Hazards Associated with Radioactive Fallout Material - I. Estimation of γ and β -Doses", Health Physics 5, 63, 1961.

11. Pretre, S., "Importance Biologique Relative des Doses Beta de la Peau Comparees aux Doses Gamma du Corps Entier", Section ABC 33/22 Bulletin ABC No. 7, April 1965.

http://www.osti.go OSTI Identifier: 4822127 Report CONF-680507 (31 October 1969): Radiological Protection of the Public in a Nuclear Mass Disaster, Symposium, Interlaken, Switzerland, 26 May-1 June 1968

BASIC CHARACTERISTICS OF NUCLEAR RADIATION FROM FALLOUT

C. Sharp Cook
U. S. Naval Radiological Defense Laboratory
San Francisco, California 94135, U.S.A.

Radioactivity may also be produced by neutron interactions within the weapon itself. In many weapons the primary radiation of this type is ^{239}Np (half-life, 2.3 days) produced by the reaction $^{238}U(n,\gamma)$ $^{239}U(\beta)$ ^{239}Np because of the presence of ^{238}U (see pp. 1690-91 of reference 17). The nuclide ^{239}U decays with a half-life of only 23.5 minutes so usually is not observed in significant amounts in fallout measurements.

Other materials besides uranium can be introduced into the regions surrounding the active portions of a nuclear weapon. These materials are then subjected to a tremendous neutron flux density when the weapon is detonated, with the result that many radioactive nuclei are formed. At one time the hazards produced by gamma radiations of a so-called cobalt bomb were discussed extensively. Based on what he considered reasonable assumptions, Dunning[18] calculated the residual-radiation exposure and exposure rate that one could expect from a one megaton nuclear weapon, containing cobalt, that derived half of its energy from fission and half from fusion. His conclusions are that the effect of the cobalt is almost insignificant at very early times but it becomes appreciable after several days. For example, his calculations indicate that one hour after detonation the gamma-ray exposure rate produced by the fission products is about 5.9×10^5 times the exposure rate produced by the ^{60}Co gamma rays, but after 30 days the fission-product exposure rate is only 0.02 times the ^{60}Co exposure rate. An infinite time extrapolation shows the contribution to the total-exposure by fission-product radiations and by ^{60}Co radiations to be approximately equal.

Comparison of Fallout and Fission Product Gamma-Ray Spectra

Cook[19] has compared calculations by Nelms and Cooper[15] of expected gamma-radiation spectra from radioactive fission-product nuclides with measured gamma-ray spectra of fallout samples. These comparisons indicate that there is a reasonably close resemblance between calculation and experiment for photons with energies greater than 290 keV. However, the ^{239}Np radiations in the experimental measurements usually completely obliterate the fission-product radiations in the energy regions between 100 and 290 keV.

(Np-239 and U-237 (in thermonuclear bombs) emit easily shielded soft ~ 0.1 MeV gamma rays.)

Experiments Using Real Fallout Fields

Mather et al.,[56] Huddleston et al.,[57] and Frank[58] have measured the gamma radiation emitted by fallout that resulted from two near-surface bursts at the Nevada Test Site. All three groups used scintillation spectrometers, with NaI(Tl) detectors, to measure pulse height distributions.

The effect of ground roughness has been determined in these experiments by measurements of the direct component of the radiation.

In both cases the effect of ground roughness could be simulated by assuming a plane source covered by a layer of earth. In the area where Mather et al. made their measurements, the layer of earth amounted to a thickness of 0.45 g/cm^2 plus 106 cm of air, and in the area measured by Frank a thickness of 0.95 g/cm^2 plus 122 cm of air.

Huddleston et al. compared their dose vs. angle of incidence measurements with a calculation by Spencer[44] to determine the effects of ground roughness. They found angular distributions from measurements made three feet above the surface which, when compared with calculations made by Spencer, are comparable to the radiation expected in air about 40 feet above a planar infinitesimally thin source. Further, they found the distribution over a dry-lake bed to closely approximate Spencer's calculated distribution for an air-equivalent distance of 20 feet, and over a plowed field an air-equivalent distance of between 40 and 60 feet.

The equivalent air thickness reported by Huddleston et al. is somewhat greater (if converted to g/cm^2) than the equivalent earth thicknesses reported by Mather et al. and by Frank. The differences may have real significance or they may possibly depend on assumptions made in the calculations. The general conclusions derived from these results are that the use of an equivalent air attenuation to represent the soil attenuation produced by ground roughness effects appears to give results that are in reasonably good agreement with experimental observations.

17. Congress of the U. S., Special Subcommittee on Radiation, "The Nature of Radioactive Fallout and Its Effect on Man." U. S. Government Printing Office, Washington, D. C., 1957.

18. G. M. Dunning, Health Phys. 4, 52-54 (1960).

19. C. S. Cook, Health Phys. 4, 42-51 (1960).

15. A. T. Nelms and J. W. Cooper, Health Phys. 1, 427-441 (1959).

56. R. L. Mather, R. F. Johnson, and F. M. Tomnovec, Health Phys. 8, 245-260 (1962).

57. C. M. Huddleston, Q. G. Klingler, and R. M. Kinkaid, Health Phys. 11, 537-548 (1965).

58. A. L. Frank, Health Phys. 12, 1715-1731 (1966).

44. L. V. Spencer. Structure Shielding Against Fallout Radiation from Nuclear Weapons. Nat. Bur. Std. Monograph 42 (1962).

THE NATURE OF RADIOACTIVE FALL-OUT AND ITS EFFECTS ON MAN

HEARINGS

BEFORE THE

SPECIAL SUBCOMMITTEE ON RADIATION

OF THE

JOINT COMMITTEE ON ATOMIC ENERGY
CONGRESS OF THE UNITED STATES

EIGHTY-FIFTH CONGRESS

FIRST SESSION

ON

THE NATURE OF RADIOACTIVE FALLOUT AND
ITS EFFECTS ON MAN

MAY 27, 28, 29, AND JUNE 3, 1957

PART 1

Printed for the use of the Joint Committee on Atomic Energy

UNITED STATES
GOVERNMENT PRINTING OFFICE
93299° WASHINGTON : 1957

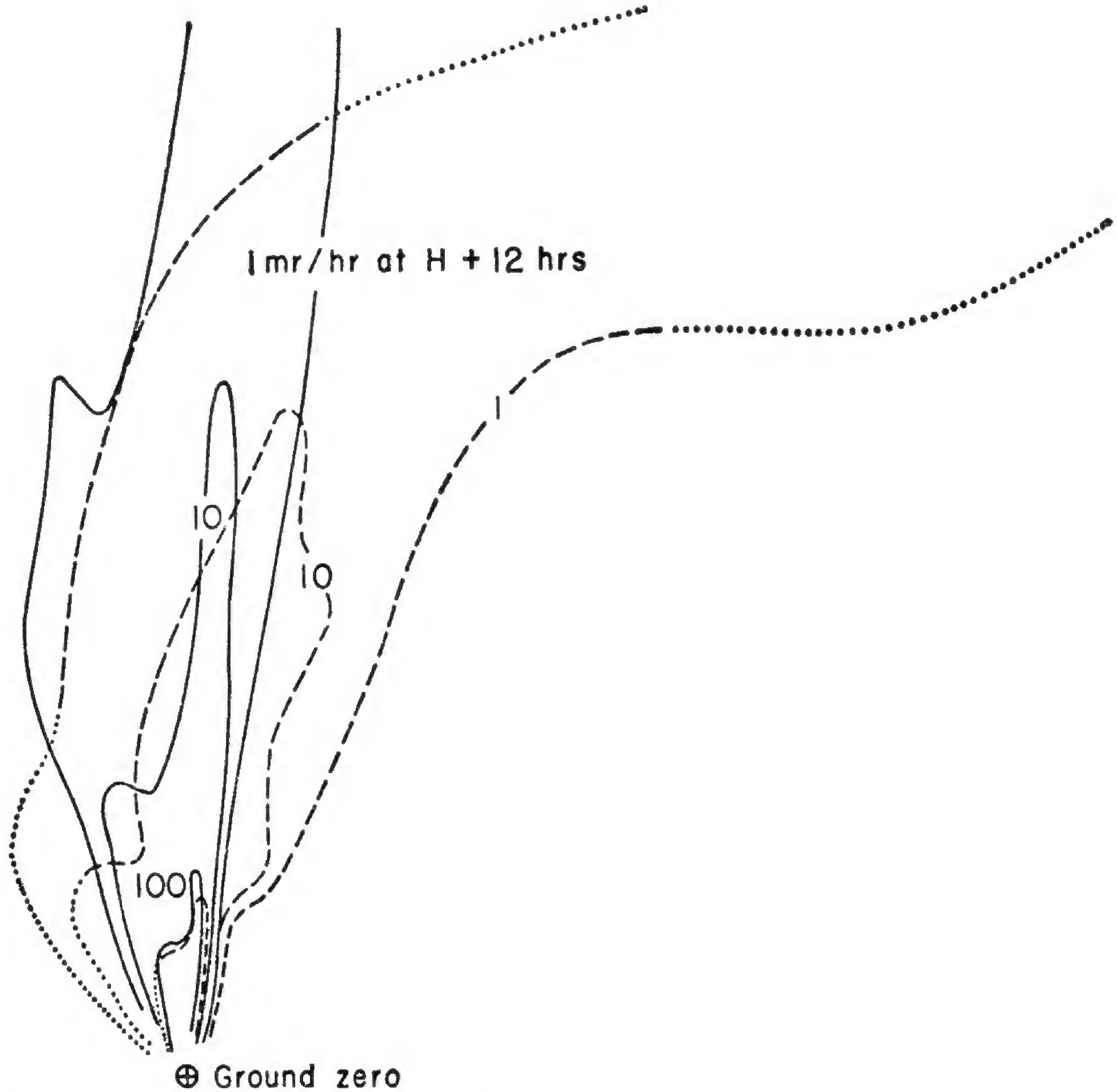


FIGURE 4.—The observed fallout distribution (dashed lines) and the pattern computed by the Weather Bureau using winds predicted at H–2 hours. May 5, 1955.

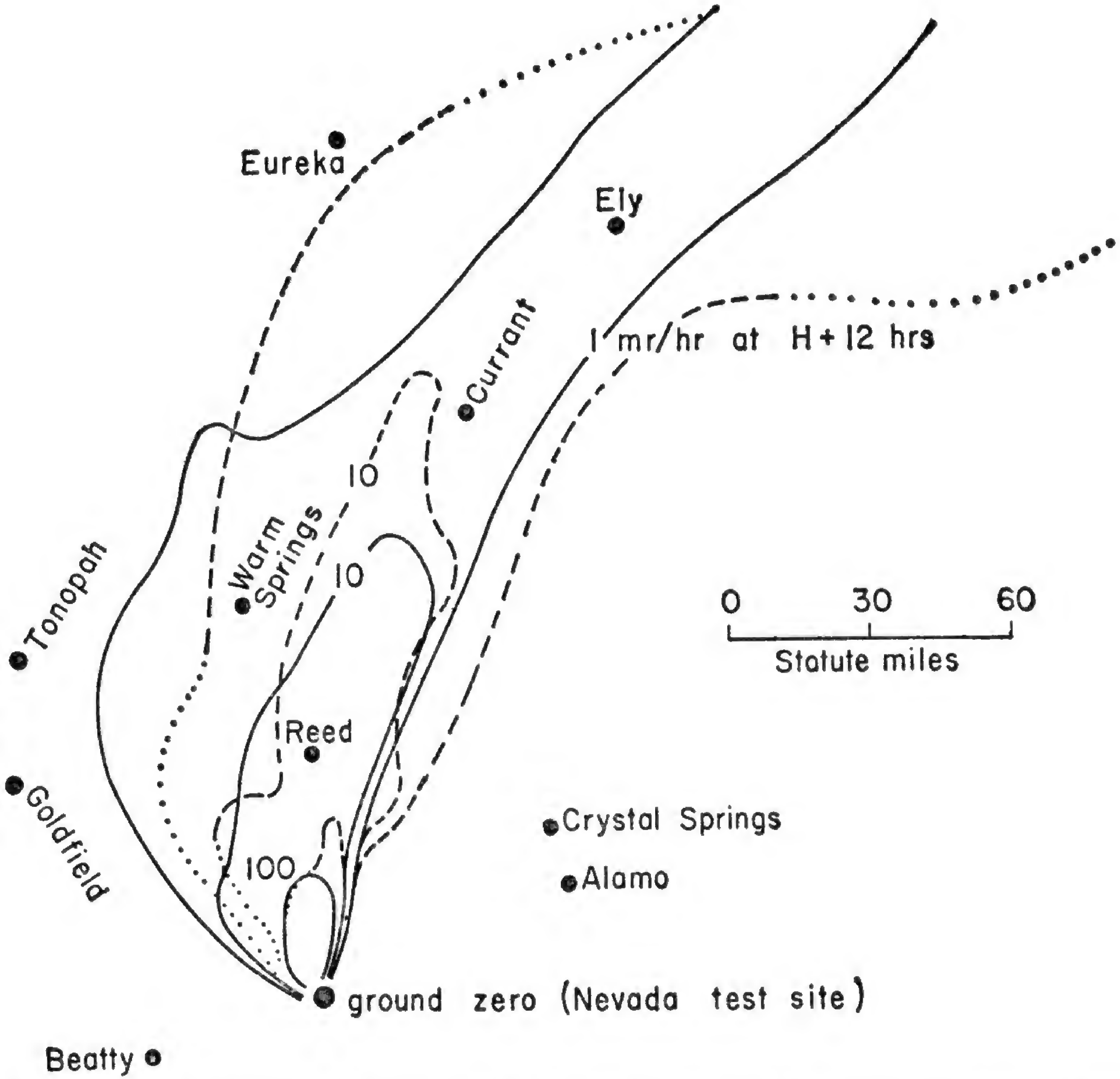


FIGURE 6.—The observed fallout distribution (dashed lines) and the pattern reconstructed by the Weather Bureau using a hand computation with time and space variation of winds (solid lines). May 5, 1955.

MYRON B. HAWKINS (b. 1920), USNRDL:

~~tion.~~[1,2,3,4] The contaminability of targets as related to micrometeorology and geometry have not been studied directly, but some information has been derived from experiments with other objectives.[5] As an example, a ship was exposed to fallout from a deep-water detonation.[6,7] The fallout arrived in a 15- to 20-knot wind on the starboard beam.

The following results were obtained:

(*a*) The contamination level (240 readings) on horizontal surfaces varied from 16 percent to 400 percent of the average, i. e., the largest was 25 times higher than the lowest.

(*b*) The gamma radiation level at 3 feet above the deck varied by a factor of 10.

(*c*) The average contamination level for vertical surfaces varied from the average horizontal reading as follows:

1. Forward part of the ship: 40 percent of horizontal average.
2. Aft part of the ship: 20 percent of horizontal average.
3. Lee side: 10 percent of horizontal average.
4. Windward side: approximately equal to horizontal average.

(*d*) Test panels at the stern of the ship had an average contamination level on vertical surfaces three times higher than levels on horizontal surfaces.[8]

Such data cannot be extrapolated or used for predictions without a better understanding of all of the factors involved.

In another example, small buildings and panels of typical building materials were exposed to fallout from land detonations.[4] The contamination levels on typical roofing materials was as much as 300 times higher than that on typical wall panels; or a vertical to horizontal relationship of about 0.3 percent. For panels of the same material, vertical readings were about 10 percent of the horizontal.

The two examples indicate considerable difference in the vertical to horizontal relationships. The characteristics of the fallout appear to have had a considerable influence on this distribution. For instance, the land detonation normally produces a "dry" fallout composed primarily of material from the crater. One can expect masses of 3 to 300 grams of material per square foot to be associated with significant radiation levels at early times. The fallout being a dry powder has little tendency to stick on vertical surfaces.

The fallout from deep-water detonations is largely composed of sea water salts. However, much of the water may evaporate, leaving particles that are damp, semicrystalline masses of a sticky nature. They are capable of sticking to vertical surfaces.

As indicated very little is known of the overall problem of contaminability. It is obvious, however, that two assumptions often made, i. e., ((1) that the fallout is distributed homogeneously on a uniform infinite plane, and (2) that vertical surfaces are not appreciably contaminated) are subject to serious limitations. The ability of a tactical force and/or a civilian population to exploit the variability of the fallout pattern depends upon knowledge we do not have on contaminability.

The contaminability of personnel exposed to the fallout event or working and living in contaminated environments is largely unknown. A study[9] indicating the significance of beta contact hazard to personnel and a requirement for the mass decontamination of personnel, emphasizes the need for additional contaminability information.

---

[1] Gevantman, L. H., B. Singer, T. H. Shirasawa, Contaminability of Selected Materials, USNRDL—TR-11.

[2] Gevantman, L. H., J. F. Pestaner, B. Singer, D. Sam, Decontaminability of Selected Materials, USNRDL–TR-13.

[3] Lane, W. B., R. K. Fuller, L. Graham, W. E. Shelberg, Laboratory Studies of the Decontamination of Repeatedly Contaminated Surfaces, USNRDL–TR–59 (confidential).

[4] Strope, W. E., Protection and Decontamination of Land Targets and Vehicles, Operation Jangle, project 6.2, AFSWP–WT–400.

[5] Lee, H., M. B. Hawkins, Some Considerations of the Geometrical Distribution of Fallout Radiation Sources Over Targets, Proceedings of the Shelding Symposium held at USNRDL October 17–18, 1956, vol. II (USNRDL report in preparation), secret.

[6] Molumphy, G. G., Captain, USN, Bigger, M. M., Proof Testing of AW Ship Countermeasures, Operation Castle final report, project 6.4, USNRDL 0012361.

[7] Lee, Hong, Technical Survey Data for Operation Castle, project 6.4, USNRDL TM-49.

[8] Maloney, Joseph C., et al., decontamination and protection, Operation Castle, project 6.5, AFSWP–WT–928.

[9] Broido, A., Teresi, J. D., requirements for mass decontamination of personnel, USNRDL–TR–38, April 1955 (secret RD).

Cost of Reclamation

Considerable data has been collected regarding the effectiveness of reclamation of targets contaminated by local fallout. The feasibility of applying these methods depends upon the following parameters:

(*a*) The time required to perform the reclamation must be short enough to make an appreciable saving in radiological exposure to mission personnel,

(*b*) The radiation exposure to reclamation personnel must be justified by the saving in exposure of mission personnel,

(*c*) The effort (manpower) and logistics required to reclaim the target must be compatible with the total effort available.

Thus, the cost of reclamation as measured in operating time, effort, radiation exposure, equipment, and supplies is an important determination.

It is impossible to generalize on these quantities for they are influenced by many factors.

The type of fallout, whether it be from a deep water, harbor or land detonation, influences the rate and/or method of decontamination. A deepwater-type fallout can be removed only to an extent of about 60 percent for a firehosing, scrubbing operation on ships,[1] the rate being about 40 square feet per minute. The same decontamination procedure at 6 times the rate of operation on a paved area contaminated by dry-land-type fallout will yield a removal of about 98 percent.[2] To achieve an equivalent removal on the ship, a surface removal technique would be required. Typical rates of operation are about 20 feet per minute for paint stripping[3] and about 7 feet per minute for removing a ⅛-inch thick layer of wood from the flight deck.[4]

The amount (or mass) of fallout on a surface influences the rate, particularly for harbor and dry-type fallout that must be transported over horizontal surfces for considerable distances. The following table shows an example of how the rate decreases with increasing masses of dry fallout for motorized flushing.[2]

Dry fallout gm/ft:[2]	*Motorized flushing rate, ft.^{2}/min.*
10	670
33	650
100	580
330	300

The mass of fallout has no effect on the rate of operation for surface removal or earth moving techniques.

The rate of operation is influence by the surface characteristics of the target, rough surfaces, e. g., wood shingles, requiring longer time than smooth, e. g., metal surfaces. The following table is an example of the influence of surface roughness on rate of operation:[2]

Firehosing of dry contaminant

Material	Effectiveness (percent removed)	Rate (ft^2/min/hose)
Corrugated metal	97	65
Composition shingles	95	50
Wood shingles	89	35

The rate of reclamation by earth moving is influenced by soil characteristics. Standard earth moving practice has developed considerable information on this subject.

---

[1] AFSWP, ITR 1323, preliminary report, Operation Redwing, project 2.9, Standard Recovery Procedure for Tactical Decontamination of Ships. Confidential.

[2] Field Evaluation of Cost and Effectiveness of Basic Decontamination Procedures for Land Target Components, Sartor, J. D., Curtis, H. B., etc., USNRDL–TR in preparation. Unclassified.

[3] Rates approaching 50 square feet per minute are possible if removal of only the surface layer of paint gives the required reduction in radiation intensity.

[4] Proof Testing of AW Ship Countermeasures, Operation Castle, project 6.4 WT-927, Molumphy, Bigger. Confidential.

The degree of mechanization obviously influences rate of operation. The following example compares firehosing rate with that of motor flushing for harbor-type fallout. Also shown are the influence of mechanization on effort and radiation exposure.[2] [5]

Criteria for comparison	Actual performance or cost		
	Firehosing	Motorized flushing	Relative cost FH/MF
1. Operating rate per unit, hr/10^6 ft^2	222	30	7.4
2. Personnel required per unit	5½	2	2.75
3. Effort (direct labor), man-hr/10^6 ft^2	1,210	60	20.0
4. Radiation shielding factor	1.0	0.5	2.0
5. Relative cost in radiation dose	1,210	30	40.0

Target complexity obviously influences rate of operation. For optimum performance, spacings between target components must be large enough to permit mechanized equipment to be used.

A simplified example will help indicate the time, manpower, and basic supplies required for recovery of a target complex. The following criteria are assumed:

(*a*) Target: City of San Francisco.
(*b*) Fallout: Harbor-type at 33 gms/ft^2.
(*c*) Area to be recovered: About 25 square miles consisting of—
1. All paved areas.
2. All industrial and commercial areas and buildings.
3. 50 percent of the park areas.
4. 10 percent of the residential areas and buildings.

(*d*) Methods: Firehosing and earth moving.

The following table indicates an estimate[5] of the cost of reclaiming these critical areas:

Cost of decontaminating critical areas of San Francisco through use of available firefighting and earth moving equipment for removing slurry contaminant

	Firehosing			Earth moving, land areas	Grand total
	Roofs	Paved surfaces	Subtotal		
1. Time to complete decontamination (24-hour days)	16.8	11.7	28.5	13	
2. Direct labor (number of men)			4,000	2,800	6,800
3. Total labor, direct and support (number of men)			6,000	4,900	10,900
4. Total effort (8-hour man-days)	101×10^3	70×10^3	171×10^3	64×10^3	235×10^3
5. Labor cost at $10 per man-day			$\$1.71\times10^6$	$\$0.64\times10^6$	$\$2.35\times10^6$
6. Water required for decontamination (gallons)	362×10^6	314×10^6	676×10^6		
7. Fuel required (gallons):					
(*a*) Gasoline	145,000	101,000	246,000	95,000	341,000
(*b*) Diesel fuel				195,000	195,000

As can be seen, the reclamation is feasible in what appears to be a reasonable time. The amount of equipment required is within the capability of existing sources in San Francisco. The manpower is not too excessive considering the numbers of people available. The water requirements are within the capability of the normal supply. Fuel consumption is less than normal daily requirements. The greatest problem would undoubtedly be that of organizing, training, supervising, and controlling 11,000 men.

Automatic decontamination devices such as the washdown system have, as an important advantage, the capability of reclamation at very early times with no expenditure of manpower or radiation exposure. They can be extremely effective (i. e., removal of 90–95 percent) even on sea-water-fallout.[4] However, they do require expenditure of funds before the war begins.

[5] Engineering Approach to Radiological Decontamination, Hawkins, M. B. (Paper to be given ASME semiannual meeting, San Francisco, June 1957.) Unclassified.

THE NATURE OF RADIOACTIVE FALL-OUT AND ITS EFFECTS ON MAN

HEARINGS

BEFORE THE

SPECIAL SUBCOMMITTEE ON RADIATION

OF THE

JOINT COMMITTEE ON ATOMIC ENERGY
CONGRESS OF THE UNITED STATES

EIGHTY-FIFTH CONGRESS

FIRST SESSION

ON

THE NATURE OF RADIOACTIVE FALLOUT AND ITS EFFECTS ON MAN

JUNE 4, 5, 6, AND 7, 1957

PART 2

Printed for the use of the Joint Committee on Atomic Energy

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1957

93299°

APPENDIX 10

OAK RIDGE NATIONAL LABORATORY,
Oak Ridge, Tenn., August 21, 1957.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Washington, D. C.

DEAR MR. RAMEY: Enclosed please find a copy of the material concerning topic VIII D of the outline, fallout and water decontamination, requested by Congressman Holifield for the Joint Committee on Atomic Energy Report.

Enclosed is the biographical sketch also requested in your letter of June 19, 1957.

If I can be of any further assistance to you and the committee, please feel free to write.

Thank you.

Very truly yours,

WILLIAM J. LACY,
ERDL Representative at ORNL.

Enclosures: 1. Report on Fallout. 2. Biographical sketch.

Cc: Commanding Officer, Engineer Research and Development Labs, Fort Belvoir, Virginia; Harry N. Lowe, Jr., Chief Sanitary Engineering Branch, Fort Belvoir, Virginia; Dr. Karl Z. Morgan, Director, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

BIOGRAPHICAL SKETCH

William J. Lacy was born in 1928 in Wallingford, Connecticut, attended Lyman Hall High School where he won the prizes in science and chemistry, then he obtained a B. S. degree in 1950 from the University of Connecticut where he majored in Chemistry. He entered graduate school at New York University in September of 1950 and worked as a research associate on an AEC research contract. In May of 1951 he joined the staff at the Engineer Research and Development Labs of Fort Belvoir, Virginia, and immediately was transferred to the Oak Ridge National Laboratory to work on the water decontamination research project.

He has had seven (7) articles published, presented numerous papers and is a member of the American Chemical Society, American Association for the Advancement of Science and the Scientific Research Society of America.

Mr. Lacy is married and has two (2) sons, 2½ and six months, he resides in Oak Ridge, Tennessee.

[Material for Joint Committee on Atomic Energy Topic VIII D]

REMOVAL OF RADIOACTIVE FALLOUT FROM CONTAMINATED WATER SUPPLIES

William J. Lacy, Chemist,* Sanitary Engineering Branch, Engineer Research and Development Labs, Fort Belvoir, Va.

There are two possible sources of radioactive contamination of public water supplies, (1) the result of direct discharge into the environment from reactor processing plants, research center using radioisotopes and others and (2) deposition of radioactive material by fallout or wash-in due to weapon's test activities.

Most of the radioactive materials in item one are in solution, fallout, however, may be in the form of insoluble oxides, and its removal may differ from the removal of ionic material.

Studies have been reported on the subject of fallout in particular areas (1), (2), (3), (4). It was reported that 35 percent of the fallout activity was removed by the Albany, New York, water treatment plant, an alum coagulation, settling and filtration plant. Thomas and his coworkers at Harvard (2) (3) working at the Lawrence, Massachusetts, water plant obtained 80 percent removal by coagulation, settling, and filtration. Bell (4) compared the fallout removal results from Cambridge and Lawrence, Massachusetts, and Rochester, New York, with pilot plant results obtained by Straub (5) (6) who used a simulated bomb blast mixture with an age about one month after detonation.

*On loan to Health Physics Division, Oak Ridge National Lab., Oak Ridge, Tennessee.

The comparison indicated the three treatment plants show much lower removals of fallout than Straub obtained on chemical processed radioactive material even though the same procedure was used in both cases. The U. S. P. H. S. reported the analysis of rain water samples containing fallout showed 50 to 100 percent of the "old" radioactive material to be soluble. However, the soluble fraction dropped to about 30 percent during the weapon's testing period.

For reactor made fission products, or a mixture of commercially available radioisotopes, the efficiency of removal would be a function of the various radioelements comprising the mixture. Results in laboratory studies and pilot plant scale investigations by the author indicates removals of about 70 to 85 percent using either alum and soda ash or ferric chloride and limestone coagulants. A series of studies (7) reported that removals of 99 percent could be obtained using a serial coagualtion procedure including an excess lime-soda ash softening or phosphate coagulation step, provided some clay material was added to remove radiocesium.

Conventional wastes treatment processes include coagulation, settling, and filtration, plus disinfection. Often additional treatment, such as fluoridation, aeration, softening, ion exchange, iron and manganese removal are employed.

During coagulation certain of the dissolved constituents are precipitated as insoluble hydroxides or carried along, scavenged, with the heavy metal hydroxides of alum or iron. Coagulation can have its radioactivity removal increased from about 75 percent to almost 90 percent by the addition of clay for cesium and copper sulfate for radioiodine.

It should be pointed out that different radioisotopes respond differently to removal by coagulation. Other factors to be considered include: (1) Chemical and physical form of the radionuclide, (2) concentration or the radioactive material, and (3) optimum pH of flocculation for the coagulant available and the water under treatment. Investigation by the author (8) indicates increase dosages of chemical generally yielded only slightly higher removals while higher pH usually resulted in proportionately higher removals.

Softening using lime-soda ash is one of the more effective chemical methods for the removal of radiostrontium and barium. However, it is necessary to use excesses quantities, over the stoichiometric dosage, for satisfactory results. Studies at MIT (9) (10) have indicated that the radiostrontium is removed by coprecipitation with the hardness or calcium carbonate in a mixed crystal formation.

Ion exchange is another method used by some municipal water treatment plants. Removal of ionic radionuclides by this process is not only technically possible (11), but very satisfactory. The most effective method employes either a mixed bed principal or separate cation-anion exchange columns. Ion exchange units such as home-type water softeners are very effective for removal of 99^{+} percent of the radioactive fallout or reactor originated radionuclides from contaminated water. Also ion exchange resins (mixed) can be used with, good results, as slurries for the removal of a vaniety of radioactive contaminants from water solutions (12)

Other methods, such as, the use of clays, powdered metal, charcoal, flotation and various adsorbents all have some merit for the removal of specific radioisotopes or under a given set of condition result in good removals. (13) However, clay seems to have the most practical and over advantage of being (1) available, (2) cheap, (3) effective, (4) simple to use, (5) easy to remove both absorbent and absorber and the radioactive material will not be easily leached once it is attached to the clay particle. Distillation although not a usual municipal water treatment method is used extensively by the military on island bases and where a high quality of water is required. Distillation results in the best single treatment of a contaminated water removing 99.9^{+} percent. (14) The major objection to distillation as a water treatment procedure is cost.

As indicated by the literature cited most of the above studies have been made on chemically processed, radiochemically pure radioisotopes and not true fallout from a nuclear detonation. Therefore, it was expected that the actual fallout material not being entirely in the same physical and chemical form could not be as readily removed from contaminated water. However, recent tests by the Corps of Engineers at the AEC Nevada Proving Grounds on some very low level fallout indicated (1) close agreement with laboratory results on removal by coagulation and softening using lime-soda ash and precipitation with trisodium phosphate at a high pH, (2) the ion exchange procedures resulted in 99 to 100 percent removal of the bomb fallout material, (3) the material that was not

a true solution could be removed physically and the material in solution treated chemically and (4) radionuclide once adsorbed on clays were not appreciably leached by tap water.

Many other experiments have been made by myself and others, some are still in progress, which have not been cited here. It is felt that this brief general review plus the six tables showing detailed data, will give the committee a review of the field on water decontamination.

REFERENCE CITED

1. Kilcawley, E. J., H. M. Clark, H. L. Ehrlich, W. J. Kelleher, H. E. Schultze, and N. L. Krascella. Measurement of Radioactive Fallout in Reservoirs. Jour., A. W. W. A., *46*, 1101 (November 1954).

2. Thomas, Harold A., Jr., R. Stevens Kleinschmidt, Frank L. Parker, and Carlos G. Bell, Jr. Radioactive Fallout in Massachusetts Surface Waters. Jour., A. W. W. A., *45*, 562 (June 1953).

3. Bell, Carlos G., Jr., Harold A. Thomas, Jr., and Barnet L. Rosenthal. Passage of Nuclear Detonation Debris Through Water Treatment Plants. Jour., A. W. W. A., *46:* 10, 973 (October 1954).

4. Nader, J. S., A. S. Goldin, and L. R. Setter. Radioactive Fallout in Cincinnati Area. Jour., A. W. W. A., *46:* 1096 (November 1954).

5. Straub, Conrad P., Roy J. Morton, and Oliver R. Placak. Studies on the Removal of Radioactive Contaminants from Water. Jour., A. W. W. A., *43:* 773 (October 1951).

6. Straub, Conrad P. Removal of Radioactive Waste from Water. Nucleonics, *10:* 1, 40 (January 1952).

7. Lacy, W. J., Rollins, R. R. and Lawless, L. M. "Removal of Radioactive Material From Water by Serial Coagulation, Ion Exchange and by Charcoal Adsorption", ERDL Report No. 1451–RR, 22 June 1956.

8. Lacy, W. J. "Removing Radioactive Material from Water by Coagulation" Water and Sewage Works *100*, 10, 410 (October 1953).

9. McCauley, Robert F., Robert A. Lauderdale, and Rolf Eliassen. A Study of the Lime-Soda Softening Process as a Method for Decontaminating Radioactive Waters. Report NYO–4439. Sedgwick Laboratories of Sanitary Science, Massachusetts Institute of Technology, Cambridge, Massachusetts (September 1, 1953).

10. Nesbitt, John B., Warren J. Kaufman, Robert F. McCauley, and Rolf Eliassen. The removal of Radioactive Strontium from Water by Phosphate Coagulation. Report NYO–4435. Massachusetts Institute of Technology, Cambridge, Massachusetts. (February 15, 1951).

11. Lacy, W. J., and Don C. Lindsten "Water Decontamination, An Ion Exchange Pilot Plant Study," ORNL–CF–Report No. 55–10–153 (October 1953).

12. Lacy, W. J. and D. C. Lindsten "Removal of Radioactive Contaminants from Water by Ion Exchange Slurry" I & E Chemistry *49*, 10 (October 1957).

13. Lacy, W. J., Decontamination of Radioactively Contaminated Water by Slurry with Clay. Ind. Eng. Chem., *46:* 1061 (May 1954).

14. Lacy, W. J., D. C. Lindsten, and H. N. Lowe "Removal of Radioactivity from Water by Thermocompression Distillation" ERDL Report No. 1313 (August 53).

TABLE I.—*Coagulation for removal of radioactivity*

Contaminant	Dosage, p. p. m.	Percent removal	
		$FeCl_3$–$CoCO_3$	Alum-soda ash
Ce^{144}–Pr^{144}	50	99.2	96.1
	100	99.4	96.5
Ba^{140}–La^{140}	50	67.4	58.4
	100	70.7	58.0
Zr^{95}–Nb^{95}	50	98.1	76.4
	100	98.8	78.6
I^{131}	50	45.0	26.3
	100	63.0	35.7
P^{32}	45.7	93.3	94.1
MFP-1 [1]	29–58	60–83.7	----------
MFP-2 [2]	50	70.1	72.6

[1] MFP-1—ORNL waste containing mixed fission products.
[2] MFP-2—Simulated 30-day atomic-bomb blast mixture.

TABLE II.—*Results of lime-soda ash treatment for removal of strontium*

Treatment	Percent removal of activity
Stoichiometric amounts	75.0
20 ppm excess lime-soda ash	77.0
50 ppm excess lime-soda ash	80.1
100 ppm excess lime-soda ash	85.3
150 ppm excess lime-soda ash	97.3
200 ppm excess lime-soda ash	99.4
300 ppm excess lime-soda ash	99.7

TABLE III.—*Ion exchange column for water decontamination*

Run No.	Resin*	Contaminant	Resin capacity gal./ft.^{3}	Percent removal until breakthrough
1	Cation	MFP-1	5,700	71–82
2	Mixed bed	MFP-1	3,150	93–99+
3	Cation	MFP-2	6,000	88–96
4	Mixed bed	MFP-2	2,890	96–99
5	Cation	Zr^{95}–Nb^{95}	6,750	85–88
6	Mixed bed	Zr^{95}–Nb^{95}	2,600	92–97
7	Cation	MFP-3	3,270	85–90
8	Mixed bed	MFP-3	6,150	92–99

*Cation resin was a high capacity nuclear sulfonic acid type and mixed bed was amberlite MB-3.

NOTES

MFP-1—ORNL liquid waste material.
MFP-2—Simulated 30-day atomic-bomb debris.
MFP-3—Three year old dissolved reactor fuel element.

TABLE IV.—*Removal of radioactive contaminants from water—Resin-jar test studies (stirring time, 90 minutes, samples filtered)*

Contaminant	Initial pH	Initial activity c/m/ml	Percent removal mixed ion exchange resin, p. p. m.			
			450	900	1,800	2,700
P^{32}	8.2	5,560	47.4	74.5	96.2	99.8
Cd^{115}	8.0	7,880	37.9	45.6	91.1	99.99
Cs^{137}–Ba^{137}	8.2	8,200	15.1	14.6	69.1	99.99
Zr^{95}–Nb^{95}	8.1	6,700	98.3	98.4	99.2	99.4
I^{131}	7.5	3,200	84.5	93.5	95.6	98.1
$Ce^{141,\,144}$–Pr^{144}	7.9	4,150	98.7	99.2	99.8	99.98
Ba^{140}–La^{140}	7.6	3,490	85.1	94.5	98.8	99.9
FPM-4	8.3	13,600	82.7	90.5	97.3	99.2
FPM-5	2.7	3,400	38.4			

NOTES

FPM-4—Iodine dissolver solution aged 30 days.
FPM-5—Mixed fission product waste containing mainly Cs^{137}–Ba^{137} and Ru^{106}–Rh^{106}.

TABLE V.—*Decontamination of radioactively contaminated water by slurrying with clay*

Contaminant	pH	Clay concentration, p. p. m.	
		1,000	3,000
		Percent removal	
Ru^{106}–Rh^{106}	5.2	50.5	61.5
Zr^{95}–Nb^{95}	7.5	98.0	99.4
Sr^{90}–Y^{90}	7.7	83.4	92.9
I^{131}	7.5	4.9	3.4
$Ce^{141,144}$–Pr^{144}	8.0	99.7	99.9
Ba^{140}–La^{140}	7.8	88.8	94.3
MFP-1	8.8	82.0	86.3
MFP-2	9.0	70.0	72.8
MFP-3	7.7	79.0	83.6

TABLE VI.—*Removal of radioactive material by distillation (60 gallon/hr thermocompression unit)*

Run No.	Contaminant	Activity of feed, d/m/ml	Removal of activity expressed as decontamination factor	Percent
1	MFP-1	22,060	4.10 x 10^3	99.98
2	MFP-2	97,400	4.97 x 10^3	99.98
3	MFP-3	31,150	3.59 x 10^3	99.97
4	MFP-4	62,400	3.52 x 10^2	99.72
5	Pa^{233}	41,030	2.31 x 10^3	99.96
6	I^{131}	60,900	7.04 x 10^2	99.86
7*	MFP-5	38,910	1.09 x 10^3	99.91
8*	MFP-4	69,700	1.00 x 10^4	99.99
9*	MFP-1	12,020	1.70 x 10^4	99.99
10*	I^{131}	45,600	1.28 x 10^3	99.92
11*	Pa^{233}	25,300	5.80 x 10^3	99.98

*Glass wool reflux condenser used.

NOTES

MFP-1 was 3-year-old fission product mixture.
MFP-2 was a 2-week-old mixture from disolution of a reactor slug.
MFP-3 was composite sample or ORNL liquid waste.
MFP-4 concentrate from ORNL liquid waste evaporator.
MFP-5 mixture to simulate the material expected 10 days after atomic detonation.

APPENDIX 11

UNITED STATES ATOMIC ENERGY COMMISSION,
Washington 25, D. C., August 20, 1957.

HON. CHET HOLIFIELD,
Chairman, Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, House of Representatives, Congress of the United States.

DEAR MR. HOLIFIELD: At the suggestion of your Committee, the Division of Biology and Medicine, U. S. Atomic Energy Commission, invited the principal participants in the discussions involving predictions of future skeletal concentrations of strontium 90 in humans which took place at the recent Congressional Hearings on fallout to meet once again in an attempt, insofar as present information permitted, to reduce the degrees of uncertainty in these predictions.

This meeting took place on July 29, 1957 and I am pleased to transmit a summary report of the meeting based on the stenographic transcript and consultation with the principal participants. This report was prepared by Dr. Forrest Western, of the Division of Biology and Medicine. It is my opinion this report honestly and clearly reflects the views of the participant scientists with respect to this problem. This document, then, would appear to reflect the thinking of those scientists who have worked hardest and thought most on the subject of these predictions, and should, therefore, be a useful addition to the text of the very important and

Arguments Against Civil Defense and a Rebuttal

Some of the arguments made against civil defense were parodied as follows in a piece in the Harvard Crimson in 1962:

Recommendations by the Committee for a Sane Navigational Policy:

It has been brought to our attention that certain elements among the passengers and crew favor the installation of lifeboats on this ship. These elements have advanced the excuse that such action would save lives in the event of a maritime disaster such as the ship striking an iceberg. Although we share their concern, we remain unalterably opposed to any consideration of their course of action for the following reasons:

1. This program would lull you into a false sense of security.

2. It would cause undue alarm and destroy your desire to continue your voyage in this ship.

3. It demonstrates a lack of faith in our Captain.

4. The apparent security which lifeboats offer will make our navigators reckless.

5. These proposals will distract our attention from more important things, e.g., building unsinkable ships. They may even lead our builders to false economies and the building of ships which are actually unsafe.

6. In the event of being struck by an iceberg (we will never strike first) the lifeboats would certainly sink along with the ship.

7. If they do not sink, you will only be saved for a worse fate, inevitable death on the open sea.

8. If you should be washed ashore on a desert island, you could not adapt to the hostile environment and would surely die of exposure.

9. If you should be rescued by a passing vessel, you would spend a life of remorse mourning your lost loved ones.

10. The panic caused by a collision with an iceberg would destroy all semblance of civilized human behavior. We shudder at the prospect of one man shooting another for the possession of a lifeboat.

11. Such a catastrophe is too horrible to contemplate. Anyone who does contemplate it obviously advocates it.